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ABSTRACT

This facilitator's guide, and the videotape it accompanies, is designed to demonstrate ways in which the new visions of science education for the 21st century might be translated into classroom practice. The National Research Council's (NRC) National Science Education Standards, American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy, and other frameworks were used as guides in developing this series. The videotape presents views of real classrooms where science is being taught. Classroom situations are spontaneous and unscripted. The videotape shows how standards actually look in practice in the classroom and how teachers are guiding experiences that enable students to construct understanding and learn science processes. The guide contains information on conducting hands-on workshops including materials lists, materials sources, and handouts. The videotape focuses on grades 5 and 6. In one lesson, students learn to take their pulse rates at rest and after exercise as part of a life science study of the human body. In another unit, students are challenged to make layers of four mystery liquids in a straw. Finally, students use computers to put together a multimedia presentation on whales. Computer programs enable students to access information from a variety of sources. (PVD)

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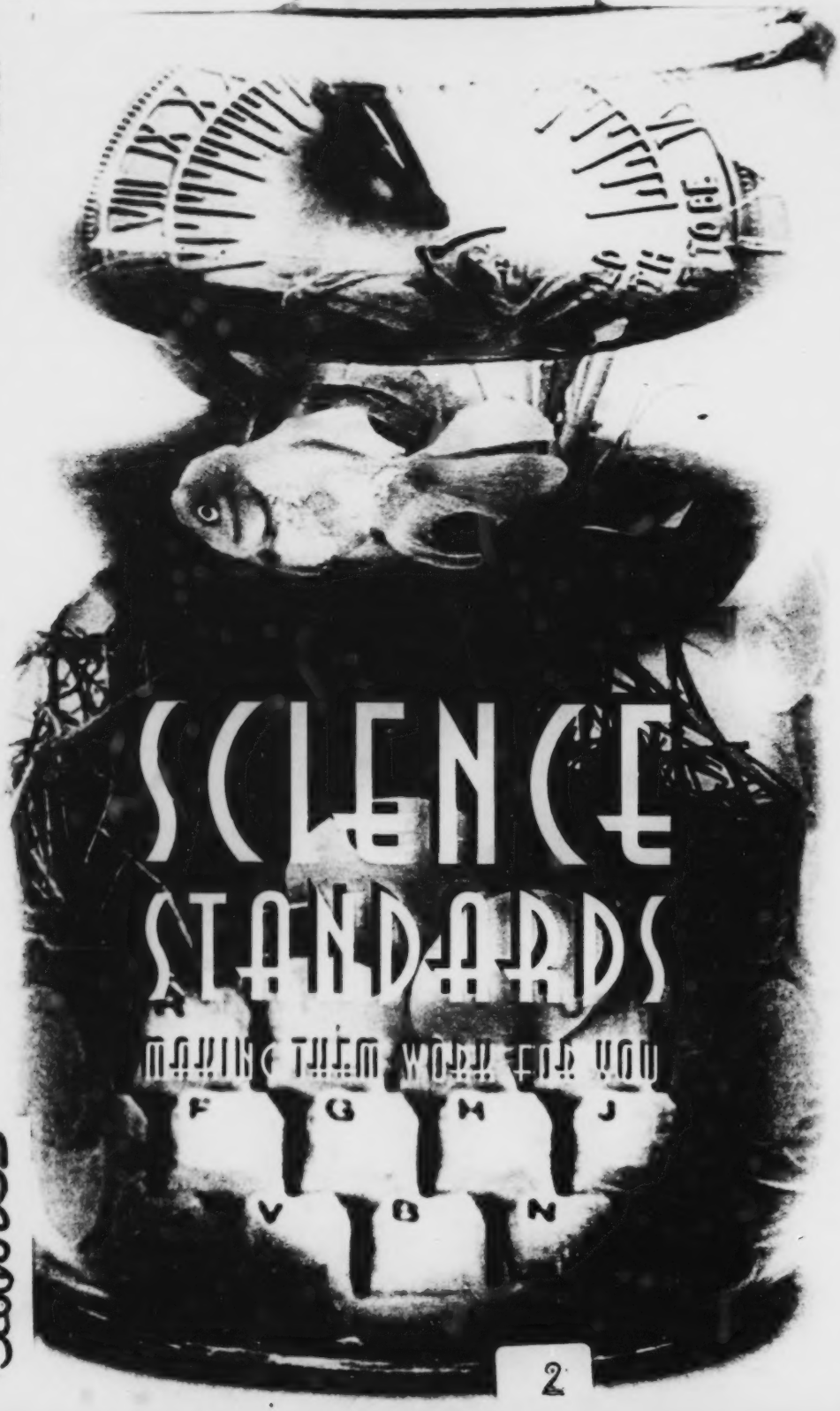

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MAKING THEM WORK FOR YOU

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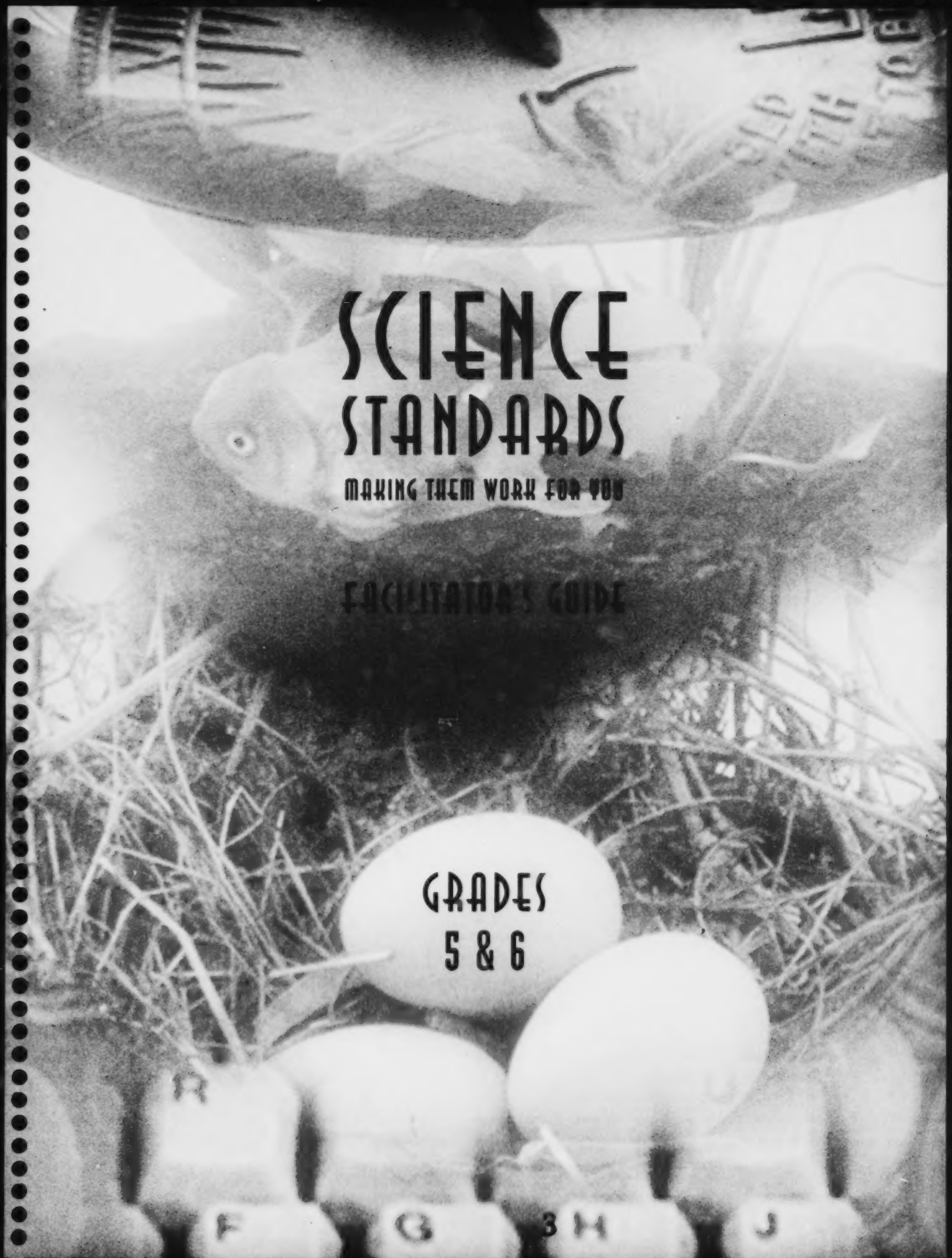
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FACILITATOR'S GUIDE
GRADES
5 & 6

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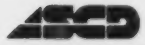

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INTRODUCTION

21st Century Science

By the time today's elementary school students graduate from high school, the world will be a very different place. Recent advances in science and technology have already caused dramatic changes in our way of life, and it's only the beginning. To prepare students for the challenges of the 21st century, scientists, educators, and other community members are formulating a new vision of science education, starting in the earliest grades. They are meeting to discuss what it means to be scientifically literate and what steps we need to take to help students achieve that literacy.

This new vision is reflected in several recent documents. *Benchmarks for Science Literacy* (American Association for the Advancement of Science, AAAS, 1993) details how students should progress toward the goal of science literacy described in *Science for All Americans* (Rutherford and Ahlgren 1990). *Benchmarks* lists the concepts that children should know by grades 2, 5, 8, and 12, in areas such as the "Living Environment," the "Physical Setting," and the "Nature of Technology." In *National Science Education Standards*, the National Research Council (NRC 1994—draft version) supports the goal of science literacy by giving standards not only for content and skills, but also for teaching science, teachers' professional development, assessment, and the entire science program and the system that provides it. The basic ideas of the AAAS *Benchmarks* and the NRC *Standards* are also found in *Frameworks for Curriculum and Instruction*, published by the National Center for Improving Science Education (1989), and in frameworks written by some states, such as California and New York.

These documents have a common goal: to produce a vision of science education that will guide reform and that will have an impact on curriculums and classrooms in the United States—and, indeed, in many other countries. It is the goal of this videotape series to show how that vision may be translated into classroom practice.

Assumptions

1. All children can learn science.

In fact, all children *must* learn science to live in an age of technology, where unprecedented amounts of information are available through computer networks. Science is not just for children of a particular gender, ethnicity, or socioeconomic class, nor is it just for future doctors, engineers and scientists, but for all students who will be facing the challenges of life in the 21st century.

2. ***Through their experiences, children (and adults) construct their own understanding of science and the world around them.***

As we grow, we constantly synthesize new information and experiences into what we already know. In this way, we make sense of our world. The study of science offers a wealth of opportunities for children to experience "discrepant events," which challenge them to search for new explanations and understandings.

3. ***Science content should be appropriate for the grade level taught.***

Activities and discussion should be designed to help children construct their own understanding of scientific concepts. Concepts should spiral through the curriculum, concentrating on thorough treatment of overarching ideas, rather than trying to "cover" a great deal of subject matter. ("Less is more.")

4. ***Children need experiences in the processes of science.***

Schools should use inquiry-oriented, hands-on, problem-solving techniques; and these strategies must replace traditional textbooks and worksheets. Like content, skills must also be appropriate for the child's developmental level, starting with basic skills such as observation, and progressing to the design of scientific experiments.

5. ***Science education should foster a positive attitude toward science.***

Teachers should be aware of the role of science studies in nurturing attitudes such as concern for the environment, understanding of what a scientist does, the value of scientific thinking, and an openness toward further learning.

6. ***Science education should start in the earliest grades.***

Children come to school with a natural curiosity about the world around them. Their curiosity and interest in science often disappears before they reach high school age. Teachers can capitalize on children's enthusiasm and use it to motivate learning, not just in science, but in other areas of the curriculum as well.

7. ***Children should learn the practical applications of science principles in the world.***

Technology, the science that deals with practical applications, is gaining momentum in the schools. Design projects and inventions help students to see the value of science in solving problems. Students also need to be aware of the adverse effects of technology and the difficult choices that must be made on a national level to use technology responsibly.

Purpose of the Program

This video series, *Science Standards: Making Them Work for You*, and the *Facilitator's Guides* are designed for administrators, teachers, parents, school board members, corporate and community leaders, and all others who are interested in improving science education at the elementary school level. We have used the NRC *Standards*, AAAS *Benchmarks*, and various frameworks as guides. The videotapes present views of science classrooms, highlighting practices that illustrate recently written science standards. The *Facilitator's Guides* contain information on conducting hands-on workshops, including lists of materials, sources of materials, and handouts.

About the Program

Teaching science presents unique problems for the elementary school teacher, problems related to classroom management, questioning techniques, and assessment of hands-on learning, to name just a few. Unfortunately, constraints of time, money, and scheduling usually prevent the one thing that would help teachers the most—observing fellow teachers at work. The videos in this series show nine classrooms where science is being taught. The classroom situations are spontaneous and unscripted. These are real classrooms representing a cross-section of the New York metropolitan area, from inner city to suburbia. We hope that these videos will enable teachers to see how standards actually look in classroom practice, and how teachers are guiding experiences that enable children to construct understanding and learn the processes of science.

This video-based staff development program consists of three 30-minute videotapes and *Facilitator's Guides*. Each videotape shows the lessons of three teachers, highlighting by "video footnotes" the practices that illustrate science standards. Tape 1 focuses on the primary grades (K–2), Tape 2 on grades 3–4, and Tape 3 on grades 5–6. All teachers should have an awareness of the concepts and skills leading up to the grades they teach, as well as the concepts and skills for which their teaching forms a foundation. Therefore, we recommend that participants view and discuss all the tapes to get an idea of the developmental flow of scientific concepts and skills, as well as an overview of issues such as curricular integration, authentic assessment, cooperative learning, and constructivism.

Program Objectives

At the end of this program, participants will be able to:

- Explain the significance of documents such as the NRC *Standards*, AAAS *Benchmarks*, and various frameworks.
- Design at least one science lesson that demonstrates effective management of materials, questioning techniques, integration, and authentic assessment.
- Describe the role that elementary science plays in preparing students for life in a technological information age.
- Recognize the motivational value of hands-on science activities.
- Identify issues and concerns involved in implementing science standards.
- Develop a personal or group plan of action related to the science standards.

Role of the Facilitator

Whether you decide to simply show the videos to a group or conduct workshops, as facilitator of this viewing process, you could be a staff developer, principal, central office administrator, or teacher. As the facilitator, your preparation for the workshop and openness to discussion will enable you to help your group benefit from this program. Remember, you may be showing this video to a diverse group, and your background knowledge and outside reading will be beneficial. As a facilitator, your major responsibilities are as follows:

- **Read and View the Materials**
  - — Have you viewed the videotape?
  - — Have you read the *Facilitator's Guide*?
- **Prepare the Program Activities**
  - — Are you prepared to guide a group through the activities and discussions necessary in the workshops?
  - — Do you have a sound background in the concepts and process presented in the videos, or do you need to do further reading?
  - — Have you tried the hands-on activities to ensure that the presentation goes smoothly?

- **Check the Room and the Seating**
  - — Have you reserved a room that is large enough, with ample seating and tables for hands-on activities? (Tables for groups of 4 work best, to model cooperative grouping.)
  - — Is the room conducive to a follow-up group discussion?
- **Arrange for a Working VCR and Monitor, and Ensure Proper Electrical Fittings**
  - — Have you arranged for the use of a VCR and monitor? (One 23–25-inch monitor will suffice for up to 25 participants.)
  - — Have you tested both machines to ensure that they are in working condition?
  - — Are the electrical outlets in the room in working order?
  - — Do you have power cords with adapters that will allow you to use the VCR?
- **Prepare Materials**
  - — Have you gathered the necessary materials for the hands-on workshops, and arranged them in trays or bags to facilitate distribution, and to model an appropriate classroom management procedure?
  - — Have you tried the activities, to see if they work for you?
  - — Have you duplicated enough handouts for all participants?
  - — Are there any supplementary articles you would like to give as handouts? (See "References and Resources" section.)
  - — Have you prepared transparencies from the "Overheads" section of this guide?
  - — Have you duplicated overheads, if necessary?
  - — Do you have extra, blank transparencies available?
- **Arrange for Other Equipment**
  - — Does the room have an overhead projector, a screen, and perhaps a flipchart?
  - — Do you have a sufficient supply of pens or markers for charts or transparencies?

- **Announce the Program**
  - — Have you specified clearly the day, month, time, and location for the program? (Remind participants to bring pencils and notepads.)
  - — Because of the subject matter of this program, have you specifically invited parents, community leaders, and business representatives?
- **Make Other Arrangements**
  - — Have you prepared the agenda, with times for breaks?
  - — Have you arranged for refreshments?

WORKSHOPS

Workshop 1

We suggest three viewing formats to meet the needs of our diverse audience. This session offers an introduction to the NRC *Science Standards*, AAAS *Benchmarks for Science Literacy*, and various science frameworks, for a group of participants who would like an overview of the topic, and a look at how these documents apply to classroom practice. This format would be ideal for an evening community-school meeting, a school board presentation, or a parent-teacher forum. It will be effective for an audience that includes parents, teachers, administrators, and community representatives. We suggest the following agenda for this 70-minute session.

Agenda and Time Guide: Workshop 1

Activity	Time (minutes)
Welcome and Introductions	5–10
Viewing the Videotape	30
Science Standards: Making Them Work for You (Grades 5 & 6)	
Reflections	20
Approximate Workshop Time	60 minutes

Workshop Materials

For this workshop, you will need copies of Handout 1 for all participants. You will also need a transparency of Overhead 1.

Welcome and Introductions (5–10 minutes)

1. Welcome all participants. Introduce yourself and explain your role as workshop facilitator. As the facilitator, you will guide the group through the workshop activities to help them address the following questions. (If you wish, show Overhead 1, "Objectives of the Workshop." In addition, you could write the following questions on a flipchart or overhead transparency.)

   - What are the implications of science standards in our school (district)?
   - How is our school (district) responding to the need for better science education?

- What kind of commitment is involved in meeting the standards for science education, in terms of resources, support, and staff development?
- What part(s) of the video interested you most?
- What questions would you like to ask the teachers depicted in the video?
- Do you think this video should be shared with a wider audience in our school, district and community? Why?
- What activities have you seen or done that illustrate the science standards?

2. Depending on the size of the group and whether the participants know each other, you may want to set aside time for participants to introduce themselves individually.

3. Distribute Handout 1, "Self-Assessment." Allow time for participants to review this handout, then ask them to state why they are interested in learning about science standards and describe briefly the extent to which they are familiar with standards.

Video-Viewing Activity (35 minutes)

1. Call participants' attention to the list of questions from your flipchart or overhead transparency.

2. Ask participants to consider, while watching the program, the effect science standards have on all students and on the roles of staff members in the featured schools. Also ask them to consider what it would take to implement standards in their curriculum.

3. View the entire video (30 minutes).

Reflections (20 minutes)

1. After viewing the video, allow participants 10 minutes to record their reactions.

2. Invite participants to engage in a discussion, based on their reactions to the video. Record their reactions on a chalkboard or flipchart.

3. After the discussion, ask participants to share their answers to the original list of questions.

4. Close the workshop by reviewing some of the key points mentioned during the discussion, and address any questions the participants may have about additional workshops.

Workshop 2

This half-day workshop is suggested for those who are familiar with the content and process of elementary science education, but wish to explore and discuss issues such as integration, assessment, classroom management, and construction of scientific concepts. The program *Science Standards: Making them Work for You (Grades 5 & 6)* is intended primarily for educators, parents, community members, businesspeople, and others interested in what recently written science standards have to say about science education. The times listed here include the time required for viewing the video and suggested times for completing the follow-up activities. You may wish to allow additional time for group discussion.

Agenda and Time Guide: Workshop 2

Activity	Time (minutes)
Introductory (Warm-Up) Activity	25
Video Viewing Activities	30
Science Standards: Making Them Work for You (Grades 5 & 6)	
Break	15
Hands-On Workshop—Monitoring Pulse Rate	40
Extension Activity: Mathematical Connections	20
Follow-up Activities	30
Concluding Activity	15
Approximate Total Workshop Time	3 hours

Workshop Materials

For this workshop, you will need, for each participant (listed in the order you will need them), copies of:

- Handout 1
- The entire "Lessons" section of the guide. (Optional—Use this for audiences that need detailed instructions and background material.)
- Handout 2
- Handout 5
- Any readings in the "References and Resources" section that you feel are appropriate.

You will also need to make the following transparencies, from the "Overheads" section (listed in the order you will need them):

- Overhead 1
- Overhead 2 (Optional)
- Overhead 3
- Overhead 4

You will also need the following materials for heart rate monitoring:

- A timer, such as a stopwatch or clock with a second hand
- Calculators, one per participant, if possible
- Pencils
- Pulse rate recording sheets (Handout 2)—one copy for each participant, and a transparency of Overhead 2 for demonstrating use of the recording sheet
- Large graph-paper chart, or a transparency of Overhead 3, "Graphing Average Pulse Rates," for recording heart rates.
- Colored markers or stick-on dots
- Adding machine tape, one roll per group of four
- Sticky tape, one roll per group of four
- Blocks or cubes, such as centimeter cubes, at least 27 per group, in plastic bags

Introductory (Warm-up) Activity (25 minutes)

1. Write the workshop objectives on the overhead, flipchart or board before the participants arrive.
2. Tell participants the following:
   - **In this activity, we will focus on what we want to accomplish in this workshop, what we think the NRC *Science Standards*, AAAS *Benchmarks for Science Literacy*, and science frameworks mean to classroom practice, and why we may want to change our approach to teaching science.**
3. At the door, have a sign-in sheet for participants to record their names, addresses, and phone numbers.

4. Introduce yourself to the participants. In addition to telling your name and what you do, write your name on a flipchart or on the board. Explain your role as the workshop facilitator. As a facilitator, you will guide the group through the workshop; you will help them meet the workshop goals. Call their attention to the goals on the overhead, flipchart, or board. (If you wish, show Overhead 1, "Objectives of the Workshop.") Briefly discuss these objectives.

5. Distribute Handout 1, "Self-Assessment." Explain the purpose of the activity by giving the following instructions:

   - **All of us have a common goal—to improve education so our children are prepared to meet the demands of our technological society. What we may not agree on is how we proceed to achieve this goal. By completing this handout, we can start this workshop with a better understanding of our feeling about the role of science in elementary education, and the implications of science standards, benchmarks and frameworks.**

   Ask participants to complete the handout.

6. Ask the participants to form groups of three or four and to share their answers with their small groups.

7. Ask the groups to report their answers to questions 1 and 2. If time allows, record the answers on the flipchart or a transparency.

Viewing the Videotape (30 minutes)

1. Introduce the videotape by telling the participants:

   - **Recent concern about the status of U.S. science education has stimulated the creation of a number of documents that describe standards for science education. Documents like the NRC *National Science Standards* and the AAAS *Benchmarks for Science Literacy* outline what students need to know and do to be scientifically literate. The video we're about to see:**
     - **introduces examples of some of the science standards,**
     - **presents examples of classrooms where standards are being implemented, and**
     - **shows what the standards actually look like in classroom practice.**

2. Before showing the video, say to participants:

   - **As you watch the program, consider what each teacher is doing and think about whether it should and could work in your school or class. What adaptations, if any, could you make for your class?**

3. Answer any simple and direct questions. Then view the entire videotape.

Break (15 minutes)

A break following the video will give the audience a chance to discuss informally what they have seen and heard so far. They can begin to internalize and organize their thoughts for the remainder of the workshop.

Hands-on Activity—Monitoring Pulse Rate (40 minutes)

1. Introduce the activity as follows:

   - **In the first segment of the video you have just seen, the students participated in a science activity that enabled them to use their math and graphing skills. In this activity, you'll have a chance to participate in one of the activities, and see how it can be expanded to develop mathematical understandings appropriate for the upper elementary grades. As you participate in the activities, put yourself in the student's place, and try to think of how the lesson contributes to understanding of the human body, while giving real-life applications for mathematical concepts.**

   Lead the participants in the model monitoring pulse rate lesson (see the preceding list, "Workshop Materials").

2. The following problem is the focus of the heart rate monitoring activity.

   Problem: How can we determine our average resting heartbeat rate?

3. Distribute multiple copies of Handout 2, "Recording Sheet—Finding Average Heart Rate." Tell participants that they are going to determine how fast their hearts are beating by counting pulses. Explain that pulses are really arteries, blood vessels leading away from the heart, which beat with the same rhythm as the heart, helping to force blood to all parts of the body.

Finding the Pulse

4. Describe and model the procedure for finding the pulse in the wrist. Use the index and middle finger of the right hand to locate the pulse on the inside of the left wrist, pressing lightly just above the midpoint of the wrist. (Reverse for lefties.)

5. You may want to explain that there are other pulse points in the body, including those that can be felt on the sides of the neck and temples. There is also a pulse in the thumb. That is the reason why the thumb is not used to take the pulse.

6. Help participants to find their own wrist pulses, and, if time permits, the pulse in the neck, or in the wrists of other students. Ask them to practice counting for short periods, on their own.

Counting Pulse Beats

7. Tell participants that they will be finding their heart rates—the number of times the heart beats per minute, by counting the number of pulse beats in a minute. Tell them to locate their pulses and begin counting the beats when the signal is given.

8. Using the stopwatch, clock, or other timer, give the signal to begin. After one minute, tell them to stop counting, and write the number on the recording sheet.

9. During the full minute of counting the pulse, some participants may have gotten restless. Tell them that most pulse counts are taken in a shorter time, such as 15 seconds. The count is then multiplied by 4 to get the rate per minute. What other methods could be used? Which would give the most accurate count?

10. Distribute the calculators.

11. Ask participants to count their pulses for a 15-second interval, write the number down in the space provided, use the calculator to multiply by 4, and record the product.

12. Ask how the number compares to the number they got when they counted for a full minute. If there is a difference of more than 4, ask why they think there was a difference. Small differences are normal. Larger differences may be the result of motion of any part of the body, standing up, nervousness, and so forth.

As much as possible, (math) problems should emerge from student activities—surveys, laboratory investigations, building projects, physical-education performance data, etc.—and the content being studied rather than from prepackaged word problems.
AAAS Benchmarks for Science Literacy

Finding the Average

13. Explain that just one reading may not give a true picture. To get a more accurate indication of heart rate over time, participants will take 3 readings, and find the average. They will have 15 seconds in between counts to record the number.

14. Tell them that they will follow your instructions about when to start and stop counting. You may want to use the following as a guide:

Clock/Watch with Second Hand	Digital Timer	
Second hand is at:	Reads:	Your directions:
the 12	00:00	Start counting.
the 3	00:15	Stop counting. Record the number.
the 6	00:30	Start counting.
the 9	00:45	Stop counting. Record the number.
the 12	01:00	Start counting.
the 3	01:15	Stop counting. Record the number.

Then instruct the participants to multiply each of the three numbers by 4.

15. Tell participants to find the average of the three numbers by adding them together, and dividing by 3.

Extension Activities: Mathematical Connections (40 minutes)

Finding Averages Concretely

1. Stop here and ask participants if they think their students truly understand the concept of average. Just finding the average by following the instructions isn't enough. Suggest the following activity to reinforce the concept, using concrete materials to find the average length of the right arms in each group.

2. Ask participants to work in groups of four. Ask one person from each group to come to the supply table and pick up a roll of adding machine tape and a roll of sticky tape.

3. Each participant should tear off a piece of adding machine tape the length of his or her arm, tape the four pieces together to form one long strip, then fold the strip in half, and in half again. The resultant length is the average of the four measurements.

Graphing Average Pulse Rates

4. Show the participants the chart on which they can record their average resting heart rates. Show them how to use a marker or colored stick-on dot to mark a square in the column corresponding to their resting heart rate. After all the participants have placed their dots, the chart will illustrate the distribution of pulse rates. Show Overhead 3, "Graphing Average Pulse Rates."

5. Analyze the graph, asking questions such as:

   - How does the graph help us organize the data? (If this is not obvious, ask participants to come to the board and write their pulse rates in a single column, in random order, and ask questions about the data.)

   - What is the range? (The range is the limit of variation in a group, going from the lowest to the highest. For instance, the normal range of pulse rates for children between the ages of 8 and 15 is 60–110.)

   - What is the median? (The median is the middle number in a distribution. For instance, if all the students in a class of 29 lined up in size places, the height of the 15th, or middle, child would be the median.)

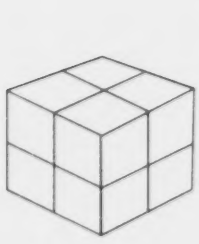
   - What is the mode? (The mode is the number that appears most frequently. It is the high point on a distribution graph. Some distributions have more than one mode.)

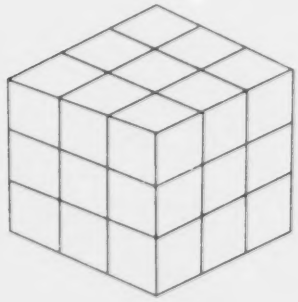
   - How can we find the average of all the heart rates? (The average is found by adding all the heart rates, and dividing by the total number of participants.)

- How can we construct graphs to tell if heartbeat rate is affected by size, gender, athletic ability, etc? (For instance, for comparing men's and women's heart rates, make a graph with two columns for each quantity. Have the women use a different colored marker to mark the proper column.)
- How do these readings compare with the heartbeat rates of other animals—cats, dogs, etc? (See science background, p. 64, and show Overhead 4, "Pulse Rates of Different Mammals.")

6. Discuss the heartbeat rates of other animals, using Overhead 4. What pattern do you see in the relationship between the size of the animal and the heartbeat rate? (Generally, people and animals that are small have a larger amount of surface area, relative to their volume. Therefore, they can lose heat more readily, and their hearts have to beat faster to bring fuel to the cells.)

7. Ask one person from each group to come to the supply table to pick up about 30 cubes. Illustrate surface-to-volume ratios in the following manner, instructing the groups to:
   - **Count the number of surfaces in one cube.** The surfaces represent units of area, and the cubes are units of volume. The surface-to-volume ratio of one cube is 6:1.
   - **Make larger cubes.** Eight blocks arranged to form a 2 × 2 × 2 cube will have 24 units of outside surface area, a 24:8, or 3:1 ratio. Twenty-seven blocks arranged to make a 3 × 3 × 3 cube will have 54 units of outside surface area, a 54:27, or 2:1 ratio.





8. Discuss the pattern that develops. As the size of the cube increases, what happens to the surface-to-volume ratio?

9. If time permits, have participants construct figures that aren't cubes, and determine their surface-to-volume ratios. What general conclusions can be drawn from their activity?

Students should start using calculators and computers early and use them in as many different contexts as possible.
AAAS Benchmarks for Science Literacy

10. Discuss the use of calculators in this activity. The AAAS *Benchmarks* and the *Standards* of the National Council of Teachers of Mathematics (1989) both urge the use of calculators as a way of enabling students to focus on difficult problems, without the tedium of paper-and-pencil calculations. Do the participants feel that students are "cheating" when they use calculators? How can we explain their use to parents?

Follow-up Activity (30 minutes)

1. Share with participants the following

   - **Here are some questions that you may be asking after viewing the video, and participating in one of the activities. Let's discuss them, and I'll jot down some of your comments:**

     - **What is your general reaction to the activities and issues shown in the videotape?**
     - **What special considerations need to be addressed by the teacher, in using the NRC *Standards*, the AAAS *Benchmarks*, and science frameworks as guides to science education?**
     - **What kind of district and administrative support is necessary for a teacher to use the standards, benchmarks, and frameworks as guides to science education?**
     - **How do the activities shown in the video compare with those in your school?**
     - **In the "Liquid Layering" segment of the video, Mary Ellis talks about using students' writing and conversations to assess their understanding. How does this assessment method compare with that in your school?**
     - **What evidence did you see that science was integrated with other curricular areas?**

- **What kinds of classroom management techniques were shown?**
- **What concerns do you have about the implications of the standards and benchmarks to elementary science education?**

Concluding Activity (15 minutes)

1. Distribute Handout 5, "Reactions to Video," and explain the following to participants:

   - **In a few minutes, I'm going to ask for volunteers to begin forming an elementary science planning team to consider the issues raised in this workshop and suggest possible strategies with which to address them. To help you in this task, you will have the notes I've taken on the discussion, and the summaries written by the recorder in each group. At a future meeting, the team will present suggestions on possible efforts to use science standards to institute change in our science program.**

2. After participants have had sufficient time to write their responses, collect the handout.
3. Ask volunteers to sign up on the sheet you will distribute, if they are interested in being a member of a planning/leadership team.
4. Set a meeting time in the next couple of weeks for the team to meet.

Workshop 3

This full-day workshop is suggested for beginning teachers and others who are unfamiliar with the content and process of elementary science education, and wish to explore and discuss issues such as integration, assessment, classroom management, and construction of scientific concepts, within the context of actual classroom situations. The video program *Science Standards: Making Them Work for You (Grades 5 & 6)* is intended primarily for educators, parents, community members, businesspeople, and others interested in what recently written science standards have to say about science education for the elementary grades. The times listed here include the time required for viewing the video and suggested times for completing the hands-on and follow-up activities. You may want to adapt this schedule by showing the video in three 10-minute segments, followed by the appropriate activities, or by conducting the activities first, then showing the video. The following is a suggested agenda for the workshop.

Agenda and Time Guide: Workshop 3

Activity	Time (minutes)
Introductory (Warm-Up) Activity	25
View Video	30
Science Standards: Making Them Work for You (Grades 5 & 6)	
Break	15
Hands-on Workshop—Pulse Rate and Mathematical Connections	45
Break	15
Computer Discussion	45
Lunch Break	60
Hands-on Workshop—Liquid Density	45
Follow-Up Activities	30
Small-Group Planning, by Grade Level	30
Concluding Activity	60
Approximate Total Workshop Time	7 hours

Workshop Materials

For this workshop, you will need, for each participant (listed in the order you will need them), copies of:

- Handout 1
- The entire "Lessons" section of the guide. (Optional—Use this for audiences that need detailed instructions and background material.)
- Handout 2
- The two *Wall Street Journal* articles in "References and Resources" section
- Handout 3
- Handout 4
- Handout 5
- Handout 6
- Any other readings in the "References and Resources" section that you feel are appropriate.

You will also need to make the following transparencies, from the "Overheads" section (listed in the order you will need them):

- Overhead 1
- Overhead 2 (Optional)
- Overhead 3
- Overhead 4
- Overhead 5

Materials for the Pulse Rate Monitoring Activity

- A timer, such as a stopwatch or clock with a second hand
- Calculators, one per participant, if possible
- Pencils
- Recording sheets—Finding Average Heart Rate—one copy for each participant, and a transparency of Overhead 2, for demonstrating use of the recording sheet

- Large graph-paper chart, or a transparency of Overhead 3, for recording heart rates (see diagram, "Distribution of Heart Rates," p. 64 of the Lessons section)
- Colored markers or stick-on dots
- Adding machine tape, one roll per group of four
- Sticky tape, one roll per group of four
- Blocks or cubes, such as centimeter cubes, at least 27 per group, in plastic bags for easy distribution

Materials for the Liquid Layering Activity

For the class:

- 4 different food colors
- Sharp knife for slicing potatoes
- Kosher or pickling salt—5 tablespoons (You may substitute table salt, but the solution will be cloudy.)
- Water—32 oz.
- Glycerin—16 oz.
- Isopropyl or denatured alcohol—16 oz.
- 2 16-oz. jars
- 4 1-qt. wide-mouthed containers with caps
- 1 tablespoon
- Measuring cup that will hold 2–3 cups
- Medicine droppers—4 for each group
- Copies of data sheet, one for each pair of participants (see Lessons, or Handout 4)
- Overhead of data sheet (listed above)

For each group of 4–6 participants:

- 6 clear plastic drinking straws (important to have CLEAR straws)
- A medium-sized raw potato
- 4 wide-mouthed clear plastic 9-oz. cups

- 4 medicine droppers
- 1 cup or other container to hold waste
- 2 or 3 paper towels
- Crayons or markers (optional)
- 1 tray

Facilitator's Setup Preparations

Before the workshop, set up the materials for the liquid layering activity:

1. Prepare the four stock solutions:

   Glycerin—add 25 drops of blue food coloring to 16 ounces of glycerin and shake well in a container. Test a drop in a straw to make sure it flows easily to the bottom. If it is too thick, add a little water until it is the consistency of syrup.

   Salt water—Mix five tablespoons of kosher salt and 20–25 drops of green food coloring in 16 ounces of water. Shake well, making sure all the salt is dissolved.

   Water—Thoroughly mix 20–25 drops of yellow food coloring with 16 ounces of water.

   Alcohol—Thoroughly mix 30–35 drops of red food coloring with 16 ounces of alcohol.

2. Cut the straws in half. (Test to see that the diameter of the straw is large enough to permit the flow of liquids.)
3. On the board, draw a diagram similar to that on the data sheet, or make an overhead of the data sheet.
4. Organize the student materials for easy distribution. On each tray, put:
   - 4 plastic cups
   - 4 medicine droppers
   - 2–3 slices of potato (Cut the potatoes shortly before the activity begins, so that they will not turn brown before they are distributed.)
   - 4–6 straw halves

- 2–3 paper towels
- 1 waste container
- Crayons or markers (optional)

5. On each tray, fill each of the four cups about one-fourth full with a different liquid. Place a medicine dropper in each cup.
6. Have extra materials on hand in a central location, in case of spills.
7. To avoid giving away part of the solution to the problem during the introduction, set up the following materials for your demonstration:
   - A cup with a small amount of the red stock solution (alcohol), adding a few drops of blue food coloring to make purple
   - A cup with a small amount of the green (salt water) solution
   - 2 medicine droppers
   - straw half
   - A slice of potato

Introductory (Warm-up) Activity (25 minutes)

1. Tell participants the following:
   - **In this activity, we will focus on what we want to accomplish in this workshop, what we think the NRC *Science Standards*, AAAS *Benchmarks of Science Literacy*, and science frameworks mean to classroom practice, and why we may want to change our approach to teaching science.**
2. At the door, have a sign-in sheet for participants to record their names, addresses, and phone numbers.
3. Introduce yourself to the participants. In addition to telling your name and what you do, write your name on a flipchart or on the board. Explain your role as the workshop facilitator. As a facilitator, you will guide the group through the workshop; you will help them meet the workshop goals. Call their attention to the goals on the overhead, flipchart or board. (If you wish, show Overhead 1, "Objectives of the Workshop.") Briefly discuss these objectives.

4. Distribute Handout 1, "Self-Assessment." Explain the purpose of the activity by giving the following instructions:

   - **All of us have a common goal—to improve education so our children are prepared to meet the demands of our technological society. What we may not agree on is how we proceed to achieve this goal. By completing this handout, we can start this workshop with a better understanding of our feeling about the role of science in elementary education, and the implications of science standards, benchmarks, and frameworks.**

   Ask participants to complete handout 1.

5. Ask participants to form small groups of three or four people and share their answers with their group.

6. Ask the groups to report their answers to questions 1 and 2. If time allows, record the answers on the flipchart or a transparency.

Viewing the Videotape (30 minutes)

1. Introduce the videotape by telling the participants:

   - **Recent concern about the status of U.S. science education has stimulated the creation of a number of documents that describe standards for science education. Documents like the NRC *Science Standards* and the AAAS *Benchmarks for Science Literacy* outline what students need to know and do to be scientifically literate. The video we're about to see:**
     - **introduces examples of some of the science standards,**
     - **presents examples of classrooms where standards are being implemented, and**
     - **shows what the standards actually look like in classroom practice.**

2. Before showing the video, say to participants:

   - **As you watch the program, consider what each teacher is doing and think about whether it should and could work in your school or class. What adaptations, if any, could you make for your class?**

3. Answer any simple and direct questions. Then view the entire videotape.

Hands-on Activity—Monitoring Pulse Rate (40 minutes)

1. Introduce the activity as follows:

   - **In the first segment of the video you have just seen, the students participated in a science activity that enabled them to use their math and graphing skills. Now, you'll have a chance to participate in one of the activities, and see how it can be expanded to develop mathematical understandings appropriate for the upper elementary grades. As you participate in the activities, put yourself in the student's place, and try to think of how the lesson contributes to understanding of the human body, while giving real-life applications for mathematical concepts.**

   Lead the participants in the model Monitoring Pulse Rate lesson (see the preceding list, "Workshop Materials").

2. The following problem is the focus of the Pulse Rate Monitoring lesson:

   Problem: How can we determine our average resting heartbeat rate?

3. Distribute multiple copies of Handout 2, "Recording Sheet—Finding Average Heart Rate." Tell participants that they are going to determine how fast their hearts are beating by counting pulses. Explain that pulses are really arteries, blood vessels leading away from the heart, which beat with the same rhythm as the heart, helping to force blood to all parts of the body.

Finding the Pulse

4. Describe and model the procedure for finding the pulse in the wrist. Use the index and middle finger of the right hand to locate the pulse on the inside of the left wrist, pressing lightly just above the midpoint of the wrist. (Reverse for lefties.)

5. You may want to explain that there are other pulse points in the body, including those that can be felt on the sides of the neck and temples. There is also a pulse in the thumb. That is the reason why the thumb is not used to take the pulse.

6. Help participants to find their own wrist pulses, and, if time permits, the pulse in the neck, or in the wrists of other students. Ask them to practice counting for short periods, on their own.

Counting Pulse Beats

7. Tell participants that they will be finding their heart rates—the number of times the heart beats per minute, by counting the number of pulse beats in a minute. Tell them to locate their pulses and begin counting the beats when the signal is given.

8. Using the stopwatch, clock, or other timer, give the signal to begin. After one minute, tell them to stop counting, and write the number on the recording sheet.

9. During the full minute of counting the pulse, some participants may have gotten restless. Tell them that most pulse counts are taken in a shorter time, such as 15 seconds. The count is then multiplied by 4 to get the rate per minute. What other methods could be used? Which would give the most accurate count?

10. Distribute the calculators.

11. Ask participants to count their pulses for a 15-second interval, write the number down in the space provided, use the calculator to multiply by 4, and record the product.

12. Ask how the number compares to the number they got when they counted for a full minute. If there is a difference of more than 4, ask why they think there was a difference. Small differences are normal. Larger differences may be the result of motion of any part of the body, standing up, nervousness, and so forth.

As much as possible, (math) problems should emerge from student activities—surveys, laboratory investigations, building projects, physical-education performance data, etc.—and the content being studied rather than from prepackaged word problems.
AAAS Benchmarks for Science Literacy

Finding the Average

13. Explain that just one reading may not give a true picture. To get a more accurate indication of heart rate over time, participants will take 3 readings, and find the average. They will have 15 seconds in between counts to record the number.

14. Tell them that they will follow your instructions about when to start and stop counting. You may want to use the following as a guide:

Clock/Watch with Second Hand	Digital Timer	
Second hand is at:	Reads:	Your directions:
the 12	00:00	Start counting.
the 3	00:15	Stop counting. Record the number.
the 6	00:30	Start counting.
the 9	00:45	Stop counting. Record the number.
the 12	01:00	Start counting.
the 3	01:15	Stop counting. Record the number.

Then instruct the participants to multiply each of the three numbers by 4.

15. Tell participants to find the average of the three numbers by adding them together, and dividing by 3.

Extension Activities: Mathematical Connections (40 minutes)

Finding Averages Concretely

1. Stop here and ask participants if they think their students truly understand the concept of average. Just finding the average by following the instructions isn't enough. Suggest the following activity to reinforce the concept, using concrete materials to find the average length of the right arms in each group.
2. Ask participants to work in groups of four. Ask one person from each group to come to the supply table and pick up a roll of adding machine tape and a roll of sticky tape.
3. Each participant should tear off a piece of adding machine tape the length of his or her arm, tape the four pieces together to form one long strip, then fold the strip in half, and in half again. The resultant length is the average of the four measurements.

Graphing Average Pulse Rates

4. Show the participants the chart on which they can record their average resting heart rates. Show them how to use a marker or colored stick-on dot to mark a square in the column corresponding to their resting heart rate. After all the participants have placed their dots, the chart will illustrate the distribution of pulse rates. Show Overhead 3, "Graphing Average Pulse Rates."

5. Analyze the graph, asking questions such as:

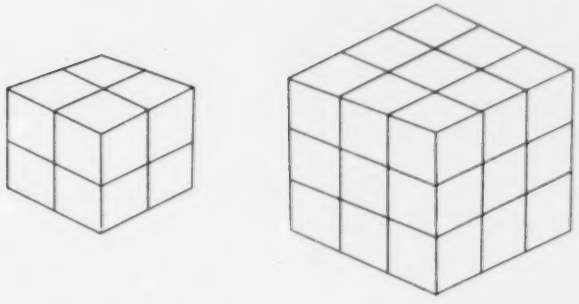
   - How does the graph help us organize the data? (If this is not obvious, ask participants to come to the board and write their pulse rates in a single column, in random order, and ask questions about the data.)
   - What is the range? (The range is the limit of variation in a group, going from the lowest to the highest. For instance, the normal range of pulse rates for children between the ages of 8 and 15 is 60–110.)
   - What is the median? (The median is the middle number in a distribution. For instance, if all the students in a class of 29 lined up in size places, the height of the 15th, or middle, child would be the median.)
   - What is the mode? (The mode is the number that appears most frequently. It is the high point on a distribution graph. Some distributions have more than one mode.)
   - How can we find the average of all the heart rates? (The average is found by adding all the heart rates, and dividing by the total number of participants.)
   - How can we construct graphs to tell if heartbeat rate is affected by size, gender, athletic ability, etc? (For instance, for comparing men's and women's heart rates, make a graph with two columns for each quantity. Have the women use a different colored marker to mark the proper column.)
   - How do these readings compare with the heartbeat rates of other animals—cats, dogs, etc? (See science background, p. 64, and show Overhead 4, "Pulse Rates of Different Mammals.")

6. Discuss the heartbeat rates of other animals, using Overhead 4. What pattern do you see in the relationship between the size of the animal and the heartbeat rate? (Generally, people and animals that are small have a larger amount of surface area, relative to their volume. Therefore, they can lose heat more readily, and their hearts have to beat faster to bring fuel to the cells.)

7. Ask one person from each group to come to the supply table to pick up about 30 cubes. Illustrate surface-to-volume ratios in the following manner, instructing the groups to:

   - **Count the number of surfaces in one cube.** The surfaces represent units of area, and the cubes are units of volume. The surface-to-volume ratio of one cube is 6:1.

   - **Make larger cubes.** Eight blocks arranged to form a 2 × 2 × 2 cube will have 24 units of outside surface area, a 24:8, or 3:1 ratio. Twenty-seven blocks arranged to make a 3 × 3 × 3 cube will have 54 units of outside surface area, a 54:27, or 2:1 ratio.



8. Discuss the pattern that develops. As the size of the cube increases, what happens to the surface-to-volume ratio?

9. If time permits, have participants construct figures that aren't cubes, and determine their surface-to-volume ratios. What general conclusions can be drawn from their activity?

10. Discuss the use of calculators in this activity. The AAAS *Benchmarks* and the *Standards* of the National Council of Teachers of Mathematics (1989) both urge the use of calculators as a way of enabling students to focus on difficult problems, without the tedium of paper-and-pencil calculations. Do the participants feel that students are "cheating" when they use calculators? How can we explain their use to parents?

Students should start using calculators and computers early and use them in as many different contexts as possible.
AAAS Benchmarks for Science Literacy

Break (15 minutes)

Discussion of Computer Segment (45 minutes)

1. Say to participants:

   - **The last segment of the video shows a class using computers to put together a multimedia presentation on whales. Like all the other segments, it shows some ways in which standards are being implemented in a school situation. Unlike the other segments, it is not a model that can be replicated by all schools. Relatively few schools can now afford the kind of equipment pictured.**

     What the segment does reflect is a *philosophy for the future of computer education.* There are important points to consider, as school districts assess what they have, and look to the future. It is possible that the computers that already exist in the school can be used in more creative ways. It is also possible that school districts are planning to invest substantial amounts of money for computer education. Before they do, they must develop a vision that reflects the use of this investment and the existing hardware in ways that will best serve the needs of students in an information age. The video brings out a number of important points that should be considered in planning for the maximum educational value from computers in the schools.

2. Introduce the Computer Discussion as follows:

   - **Please take some time to review the points listed in pages 71–73 of your Lessons section, and also to read two recent articles from the *Wall Street Journal,* which I will distribute. When you are finished, discuss the articles in your groups, using Handout 3 as a guide. Appoint a recorder/spokesperson for your group.**

Facilitator's Note

If your audience has a wide variation of computer expertise, you may want to structure the groups so that skills are evenly distributed.

3. Distribute the two *Wall Street Journal* articles (from the "References and Resources" section of this guide) and Handout 3, "Developing a Vision for Computer Education." (Allow at least 15 minutes for reading, 10 minutes for completing the handout, and the rest of the allotted time for discussion.)

4. After participants have had a chance to discuss the articles, ask for their responses.

Lunch Break (60 minutes)

Hands-On Workshop—Liquid Layering (45 minutes)

Schools that implement the Standards will have students learning science by actively engaging in inquiries of interest and importance to them.
Draft, NRC Science Standards

Students should develop an understanding of properties of objects and materials.
Draft, NRC Science Standards

1. Introduce the activity by saying:

   - **In the lesson in the video on density of liquids, students are given four different "mystery liquids," droppers, a clear plastic straw, and a slice of potato to plug the end of the straw. Then they are given a challenge: to make layers of the four liquids in the straw. By predicting, then testing and revising their predictions, they gradually gather the data necessary to reach a solution. In the process, they develop valuable process skills and form a foundation for constructing the concept of liquid density.**

   Lead participants in the model Liquid Layering lesson (see the preceding list, "Workshop Materials").

Science teaching must involve students in inquiry-oriented investigations in which they interact with the teacher and peers.
Draft, NRC Science Standards

2. The following problem is the focus of the lesson. Call participants' attention to the problem and the safety notes:

   Problem: How can different-colored "mystery liquids" be layered in a clear plastic straw?

   Safety Notes: Remind teachers to caution students not to taste any of the liquids.

   The series, Great Explorations in Math and Science (GEMS), also advises the use of the term "medicine droppers" instead of "eye droppers" to prevent children from thinking that they can put the liquids in their eyes. (For further information, contact GEMS, Lawrence Hall of Science, University of California, Berkeley, CA 94720.)

3. Introduce the problem: Participants will try to make layers of different-colored liquids in a straw.

4. Model the procedure for placing the straw in the potato at a 45-degree angle, so that the potato can act as a plug for the straw. Show them the purple and green solutions, and demonstrate the procedure using the medicine dropper to pick up some of the purple solution and drip it down the side of the straw.

5. Ask participants what will happen if you add the green solution to the straw. Allow time to discuss predictions, asking questions that begin with "Why do you think . . . ?" and "How do you know . . . ?"

6. Pick up some of the green solution in the dropper and drip it down the inside of the straw. It should sink to the bottom. Show participants the results. (Putting white paper in back of the straw will make the layers more visible.)

7. Demonstrate how to empty the contents of the straw by dumping it into the waste container.

8. Assign one person from each group to get the trays and bring them back to their tables. Ask participants to work in pairs.

9. Allow the participants to practice with one of the liquids for a short time, to master the technique.

10. Distribute the data sheets, one for each pair of participants, and describe the procedure for using them to make predictions and record data. The two partners should make a prediction and record it by writing the letters B, G, R, and Y in the appropriate order in the first diagram on the data sheet. They may also use the colored crayons or markers to record. Then they should test their predictions, and circle the combinations that worked according to their predictions. They should then make a revised prediction, record that in the same way, and continue testing and predicting, obtaining a little more information each time.

11. When a group has reached a solution, ask them to dump the liquids out and try it again, layering the liquids in the expected order, to make sure there is a clear separation of liquids.

12. Ask participants to draw and write about the results of their investigation, asking the question, "Why do you think that happened?"

13. When all or most of the participants have solved the problem, have them place the materials back on the tray, and ask one person from each group to take the tray back to the supply table.

14. Discuss the results. Ask them to list the order of layering. Did all of groups report the same results? Record the successful combinations on the blackboard diagram.

15. Ask the participants to discuss the responses of students in the video. The students started out by thinking that color was the important factor, then adapted their thinking as students discussed other ideas. One student, not included in the video, said that he noticed that the darker colors rose to the top, and that the darker colors absorbed heat, and became lighter. This idea, although incorrect, demonstrated higher-level logical thinking on the child's part. Finally, a student knew and described the word density, and the teacher was able to provide a demonstration that made sense to the class.

Children, like scientists, will propose different explanations, and some children may have a need to establish whose ideas are good or best. Comparisons will come in time, when students are able to imagine ways to make judgments. Everyone's ideas should be valued, and differing opinions should be regarded as interesting and food for thought.
AAAS Benchmarks for Science Literacy

(Students should know that) substances have characteristic properties, such as density.
Draft, NRC Science Standards

Follow-up Activity (30 minutes)

1. Say to participants:

   - **Here are some questions that you may be asking after viewing the video and participating in the activities. Let's discuss them, and I'll jot down some of your comments:**

     - **What is your general reaction to the activities and issues you have seen and experienced?**
     - **What special considerations need to be addressed by the teacher, in using science standards as guides to science education?**
     - **What kind of district and administrative support is necessary for a teacher to use the science standards as guides to science education?**
     - **How did the classrooms in the video illustrate:**

       curricular integration?
       assessment?
       classroom management?
       cooperative groups?

Small-Group Planning, by Grade Level (30 minutes)

1. Ask the participants to form small groups, by grade level.
2. Distribute Handout 6, "Small-Group Discussion/Planning."
3. Instruct participants to use the handout as an outline for their group's discussion, and appoint a spokesperson to record responses and report to the entire group.

Sharing and Concluding Activity (30 minutes)

4. After participants have had sufficient time to write their responses, invite the spokespersons to share their responses.
5. Ask volunteers to sign up on the sheet you will distribute, if they are interested in being a member of a planning/leadership team.
6. Set a meeting time in the next couple of weeks for the team to meet.

HANDOUTS

HANDOUTS

HANDOUT 1

Self-Assessment

Answer these questions as well as you can. Be as specific as possible. You'll share your answers with others in the workshop. Use separate sheets of paper, if necessary.

1. I am concerned about elementary science education because:

2. If I were writing standards for science education in the elementary grades, the most important issues I would want to address are:

3. How would science standards improve my effectiveness as a teacher?

4. How would use of the science standards as a guide improve my students' performance?

HANDOUT 2

PULSE RATES AFTER EXERCISE
Recording Sheet

Instructions

You should be seated and relaxed for this part of the activity. Find your average pulse rate as before. Count the number of pulse beats in 15 seconds, multiply by 4 to find the number of beats per minute, repeat this two more times, then find the average of the three readings.

Trial #	Beats per 15 sec	× 4	= Beats per minute
1		× 4	=
2		× 4	=
3		× 4	=
		Total	
		Divide by 3	÷ 3
		Average Resting Pulse Rate	

Within 15 seconds after exercise, return to the gathering area. When the teacher gives the signal, count your pulse for 15 seconds. The teacher will tell you when to stop counting. Record the count in the 0:00 space. Find your pulse again, and repeat the procedure until you are told to stop.

See the next page for recording sheet.

Recording Sheet—Finding Average Heart Rate

ASCD
Association for Supervision and Curriculum Development

Recording Sheet

Minute After Exercise	Pulses per 15 seconds	× 4	= Pulses Per Minute
0:00		× 4	=
0:30		× 4	=
1:00		× 4	=
1:30		× 4	=
2:00		× 4	=
2:30		× 4	=
3:00		× 4	=
3:30		× 4	=
4:00		× 4	=
4:30		× 4	=
5:00		× 4	=
5:30		× 4	=
6:00		× 4	=
6:30		× 4	=
7:00		× 4	=
7:30		× 4	=
8:00		× 4	=
8:30		× 4	=
9:00		× 4	=
9:30		× 4	=
10:00		× 4	=
10:30		× 4	=
11:00		× 4	=
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12:00		× 4	=
12:30		× 4	=
13:00		× 4	=
13:30		× 4	=
14:00		× 4	=
14:30		× 4	=
15:00		× 4	=

HANDOUT 3

Visions for Computer Education

Use this handout to record your reactions to the video program.

1. My initial reaction to the computer segment of the video, and the newspaper articles is:

2. How is computer technology being used in my school?

3. How does the current use of computers fit in with the educational philosophy of the school or district?

4. Can better use be made of the computers currently available in my school? If so, what steps would be necessary?

5. The computer education program shown in this video has the following characteristics in common with my school:

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6. The computer education program shown in this video differs from my school's in the following ways:

7. Characteristics that I did not see in the video that I would like to see in my school are:

8. With computers in mind, I'm pleased that at our school site we have:

9. With regard to computers, I'm still very concerned about:

10. I can help my school become involved in a change process related to computers by:

HANDOUT 4

Data Sheet for Liquid Layering

Use this sheet to record and revise your predictions. Write or color your first prediction in the first diagram. Test your prediction. Circle the combinations that layered according to your prediction. Make a new prediction and write or color it in the next diagram. Continue until you have solved the problem, then check your answer.

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HANDOUT 5

Reactions to Video

Use this handout to record your reactions to the program.

1. My initial reaction to the video is:

2. The benefits that I see happening through science standards are:

3. The schools on the tape have the following characteristics in common with my school:

4. The schools on the tape differ from my school in the following ways:

5. Characteristics that I did not see on the tape that I would like to be present at my school are:

6. I can help my school improve the science program by:

7. I am still very concerned about:

8. I would like to know more about:

9. In the area of science education, my school can be proud of:

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HANDOUT 6

Small-Group Discussion/ Planning

Please use the following questions as an outline for your discussion. Appoint a spokesperson to record and report for the group.

As a result of this session:

1. Three important things I've learned are:

2. Two ideas or insights I would like to share with colleagues back home are:

3. One action I will take immediately is:

4. I would like to know more about:

5. I need:

6. I can get what I need by:

7. I can make a difference in my district/school/grade/class by:

BEST COPY AVAILABLE

The videotape series shows sample lessons that illustrate what science standards actually look like in classroom practice. For teachers and anyone who wants more information on the lessons depicted, this packet contains lesson plans, background information, suggestions for integration, and other materials.

Overview

This series of lessons is intended to be part of a life science study of the human body. It illustrates the body's monitoring and control of the pumping of blood by the heart, an important body function. Students learn to take their pulse rates at rest, in different body positions, and after exercise and then graph the changes during recovery. The lessons provide real-life opportunities to use math skills in a number of ways, including finding averages, analyzing statistical data, and graphing. Use of calculators enables students to concentrate on the problem at hand, without the tedium of paper-and-pencil calculations.

Heart Rate Activities

Grades 6 through 8:
Teachers can capitalize on students' interest in their changing bodies by having them monitor and assess their basic vital signs and other health-related characteristics. Using simple tools, students can monitor their own health. The data they gather can be analyzed to show how healthy people are different.
AAAS Benchmarks for Science Literacy

Lesson 1: Finding the Average Heart Rate

Problem: How can we determine our average resting heartbeat rate?

Materials:
- ✓ a timer, such as a stopwatch or clock with a second hand calculators, one per student, if possible
- ✓ pencils
- ✓ recording sheets, "Finding Average Heart Rate," one per child
- ✓ large graph-paper chart, for recording heart rates (see diagram, p. 82)
- ✓ colored markers or stick-on dots

Procedure

1. Distribute the recording sheets. Tell students that they are going to determine how fast their hearts are beating by counting pulses. Explain that pulses are really arteries, blood vessels leading away from the heart, which beat with the same rhythm as the heart, helping to force blood to all parts of the body.

Finding the Pulse

2. Describe and model the procedure for finding the pulse in the wrist. Use the index and middle finger of the right hand to locate the pulse

on the inside of the left wrist, pressing lightly just above the midpoint of the wrist. (Reverse for lefties.)

3. You may want to explain that there are other pulse points in the body, including those that can be felt on the sides of the neck and temples. There is also a pulse in the thumb. That is the reason why the thumb is not used to take the pulse.

4. Help students to find their own wrist pulses, and, if time permits, the pulse in the neck, or in the wrists of other students. Ask them to practice counting for short periods, on their own.

Counting pulse beats

5. Tell students that they will be finding their heart rates—the number of times the heart beats per minute, by counting the number of pulse beats in a minute. Tell them to locate their pulses and begin counting the beats when the signal is given.

6. Using the stopwatch, clock, or other timer, give the signal to begin. After one minute, tell them to stop counting, and write the number on the recording sheet.

7. During the full minute of counting the pulse, some students may have gotten restless. Tell them that most pulse counts are taken in a shorter time, such as 15 seconds. The count is then multiplied by 4 to get the rate per minute. What other methods could be used? Which would give the most accurate count?

As much as possible, (math) problems should emerge from student activities—surveys, laboratory investigations, building projects, physical-education performance data, etc.—and the content being studied rather than from prepackaged word problems.
AAAS Benchmarks for Science Literacy

8. Distribute the calculators.

9. Have them count their pulses for a 15-second interval, write the number down in the space provided, use the calculator to multiply by 4, and record the product.

10. Ask how the number compares to the number they got when they counted for a full minute. If there is a difference of more than 4, ask why they think there was a difference. Small differences are normal. Larger differences may be the result of motion of any part of the body, standing up, nervousness, etc.

Finding the Average

11. Explain that just one reading may not give a true picture. To get a more accurate indication of heart rate over time, they will take 3 readings, and find the average. They will have 15 seconds in between counts to record the number.

12. Tell them that they will follow your instructions about when to start and stop counting. You may want to use the following as a guide:

Clock/Watch with Second Hand	Digital Timer	
Second hand is at:	Reads:	Your directions:
the 12	00:00	Start counting.
the 3	00:15	Stop counting. Record the number.
the 6	00:30	Start counting.
the 9	00:45	Stop counting. Record the number.
the 12	01:00	Start counting.
the 3	01:15	Stop counting. Record the number.

Then instruct the participants to multiply each of the three numbers by 4.

13. Tell them to find the average of the three numbers by adding them together, and dividing by three.

14. If students are willing, have them discuss their average resting heart rates. Be sensitive to the possibility that some students may be reluctant to share this information. Also, take note of any reading below 60 or above 110, and speak with the school nurse about the possibility of follow-up to determine whether or not the pulse is a symptom of a problem (See Recording Sheet, page 75).

Graphing Average Pulse Rates

15. Show the students the chart on which they can record their average resting heart rates (see Recording Sheet, page 77). Show them how to use a marker or colored stick-on dot to mark a square in the column corresponding to their resting heart rate. After all the participants have placed their dots, the chart will illustrate the distribution of pulse rates.

16. Analyze the graph, asking questions such as:

- How does the graph help us organize the data? (If this is not obvious, have students come to the board and write their pulse rates in a single column, in random order, and ask questions about the data.)
- What is the range? (The range is the limit of variation in a group, going from the lowest to the highest. For instance, the normal range of pulse rates for children between the ages of 8 and 15 is 60–110.)
- What is the median? (The median is the middle number in a distribution. For instance, if all the students in a class of 29 lined up in size places, the height of the 15th, or middle, child would be the median.)
- What is the mode? (The mode is the number that appears most frequently. It is the high point on a distribution graph. Some distributions have more than one mode.)
- How can we find the average of all the heart rates? (The average is found by adding all the heart rates, and dividing by the total number of students.)
- How can we construct graphs to tell if heartbeat rate is affected by size, gender, athletic ability, etc? (For instance, for comparing girls' and boys' heart rates, make a graph with two columns for each quantity. Have the girls use a different colored marker to mark the proper column.)
- How do these readings compare with the heartbeat rates of other animals—cats, dogs, etc? (See science background, p. 64.)

Students should start using calculators and computers early and use them in as many different contexts as possible.
AAAS Benchmarks for Science Literacy

Lesson 2: Heart Rate and Activity

Problem: How does body activity affect the pulse rate?

Materials:

✓ Recording sheets—Comparing Pulse Rates
✓ Timers
✓ Pencils

Procedure

1. Distribute copies of Recording Sheet C3. Have the students repeat the procedure for finding average heart rate, to establish a basis of comparison for the following activities.

2 Remind the students that they were sitting when they took the readings. Ask them if they think it would make any difference if they were standing up or lying down. Have them record their predictions in the spaces provided on the recording sheet.

3. Tell the students that they are going to repeat the procedure of finding the average pulse rate, but that they will be standing this time. Review the procedure, telling them that they will stand for one full minute, then count their pulse beats for three 15-second intervals, write the numbers down in the spaces provided, multiply by 4, and find the average of the three readings.

4. Ask students to stand at their desks and find their pulses. When everyone is ready, give the signal to begin counting, and repeat the procedure in steps 3 and 4 of the last lesson.

5. Ask students to be seated, then discuss their findings. In most cases, the average standing heart rates should be higher. Ask them why they think this happened. What is the effect of gravity on the pumping of blood?

6. If time, space and other conditions permit, have them repeat the activity while lying down, after lying down for a full minute. You may want to assign this for homework. Averages this time should be lower, because the heart isn't working so hard to overcome gravity. This emphasizes the need for rest.

7. Have students jog or walk in place for a short time (30–60 seconds).

8. Have students sit down and repeat the timing and counting procedure.

9. This time, instead of finding the average, ask students what they noticed about the three readings. (The first reading should have been significantly higher than the resting heart rate, the second reading lower, and the third lower than the second.)

10. Ask the class what they think of the readings? What might they tell us about the body's reaction to exercise, and its recovery?

11. Tell them that they will be finding out more about recovery time in the next lesson.

Lesson 3: Recovery Time

Problem: How long does it take the heart to recover after exercise?

Materials:

- ✓ copies of "Pulse Rates After Exercise" recording sheet, one for each student
- ✓ copies of " Pulse Rates After Exercise" graphing sheet, one for each student
- ✓ stopwatch or other timer
- ✓ calculators
- ✓ pencils

Note: The physical activity in this lesson may be running, jumping rope, climbing stairs, jogging in place, or any kind of exercise that is safe and appropriate for your students and the space available.

Procedure

1. Introduce the lesson by reminding the students of their experience in the last lesson, where their pulse rates were higher after exercise, but got lower as they started to recover. Tell them that they will be doing some exercise and taking their pulses, and that each student will be finding out how long it takes his or her pulse rate to return to normal after exercise.

2. Discuss the procedure for completing the lesson. Describe the location (gymnasium, stairway, outdoors, in classroom) and the type of exercise (running, climbing stairs, jumping rope). Tell them that they will be taking their pulse rates immediately after exercise, and at half-minute intervals after that, so as to return to their resting heart rate. For instance, "We are going to go to the gym, and run until you start to get tired. You will then immediately return to the bleacher area, where I will direct you in taking your pulse rate at regular intervals."

3. Distribute Recording Sheet, page 82. Repeat the procedure for finding the resting pulse rate, to establish a baseline for today's activity. Proceed to the exercise area, making sure that everyone brings the recording sheets, folded in quarters for easy carrying, and pencils.

4. Have the students put down their pencils and recording sheets in the place where you plan to have them gather. Tell them that they will have only 15 seconds to return to this area, and you will not wait for stragglers.

5. Begin the exercise activities. (You may want to participate in this.) When everyone is getting tired and breathing heavily, tell them to return quickly and be seated on the floor, bleachers, chairs, etc. for the timing.

6. Begin timing after 15 seconds. Give the signal to begin. After 15 seconds, tell them to stop timing, and write the number down on the recording sheet. Fifteen seconds later, start the timing again, give the signal to stop and record the number. Repeat the procedure for 15 minutes, or until everyone's pulse rate has returned to normal.

Note: The teacher in the video departed slightly from this procedure by starting the count at one-minute intervals. This gave the students more time to do the calculations in the gymnasium.

7. Return to the classroom, distribute the calculators and have the students use them to multiply their 15-second counts by 4 to obtain the number of beats per minute.

8. Distribute the graphing worksheets (see Recording Sheet, page 83) and model the method for constructing a graph that shows the comparison between the resting heart rate, and the recovery of the heart after exercise.

    - Draw a horizontal line across the graph, to show the resting heart rate.
    - Plot the points on the graph to indicate the pulses per minute versus the number of minutes after exercise.
    - Connect the points to form a graph.

9. As students are constructing the graphs, circulate around the room to monitor their progress and give assistance. This is a good time to listen to the comments and conversations, as a way of assessing what they have learned from the activity. (It is also a good time to be sensitive of the feelings of students who may be reluctant to share information. You may want to give them another job, such as collecting the calculators, to excuse them from the next part of the activity.)

10. Have students get together in small groups to discuss and compare recovery rates. Students may hold one graph over another, and hold them up to the light, as a way of comparing. Appoint a spokesperson to report on the group's results.

11. Call on the spokesperson from each group to report. Discuss:

- Which recovery was the shortest? Longest?
- How are the graphs that show short recovery times different from those that show long ones?
- Did any of the graphs have "peaks and valleys?" If so, what were some possible reasons?
- What can be done to decrease the time that it takes for the pulse rate to return to normal?

Science Background:

The heart is the body organ which pumps blood. The blood travels from the heart through vessels called arteries to all parts of the body. Arteries are muscular, like the heart, and beat with the same rhythm as the heart, to help the blood flow. Some arteries are located near the surface of the body, and their beating can be felt through the skin. These places are called pulses. Some of the places in which pulses occur are the wrists, temples, and neck. There is also a pulse in the thumb, and that is the reason why the thumb is not used in taking the pulse of another person. Since pulses echo the rhythmic beating of the heart, they can be used to determine the heartbeat rate. Most children between the ages of 8 and 15 have pulse rates between 70 and 85 beats per minute.

The regularity of the heartbeat is controlled by the heart's pacemaker, and variations in the rate are under chemical and nervous control.

The blood carries to the cells nutrients and oxygen, which enable the cells to carry on their life functions. It takes away wastes that would poison the cell if not removed. The heart/pulse rate varies with factors such as physical activity, nervousness, and body size.

For instance:

- During physical activity, the body cells need more energy, and the heart must beat faster to supply the necessary nutrients and oxygen and to remove waste materials.
- Even minor physical activity and body position will affect pulse rate. The pulse rate is lower when lying down or sitting than it is when standing, because the heart doesn't have to work so hard to overcome gravity.

- When a person is frightened or nervous, a complex series of events takes place, to prepare the body for emergencies. The preparation includes increased heart/pulse rate.

- Body size affects the average pulse rate. Children generally have higher pulse rates than adults. Women generally have higher pulse rates than men. The heartbeat rates for some familiar mammals are:

mouse	1000
rabbit	140–160
cat	120–140
dog	70–120
lion	40–50
horse	30–45
cow	40–70
elephant	25–47

  The larger an animal is, the less surface area it has per unit of volume, and the slower the rate of heat loss, so the heart doesn't have to pump so hard to keep the body warm. (For more information on surface to volume ratios, see the section on "Mathematical Connections.")

- Athletes may have lower pulse rates, because their training increases the efficiency of the heart, allowing it to pump more blood with each stroke.

- Recovery: After exercise, the pulse rate returns to normal. The time it takes for the pulse to recover is an indication of the fitness of the individual. People who are physically fit have short recovery times, can exercise longer without stopping, and will not be as short of breath as people with slow recovery times.

Mathematical Connections

Finding averages concretely—Students who have been taught mathematics by traditional means may know the procedure for finding the average, but not really understand what average means. It is not enough that students go through the cookbook methods for finding averages. For students who need help understanding the concept of average, the following activities are suggested:

- In groups of four, ask students to find the average length of their right arms, as follows: Give each group a roll of adding machine tape, and have each student tear off a piece of tape that is as long as

his/her right arm. Tape all four pieces together into one long strip. This corresponds to adding all the numbers. Fold the strip in half, then in half again. This corresponds to dividing by four. The length of the folded tape will be the average of the three arm lengths.

- Get three jars and 30 small objects, such as marbles, candy, or pasta. Put different numbers of objects in each jar (e.g. 11 in the first jar, 7 in the second, 12 in the third). To find the average, dump all the objects out of the jars, and distribute them evenly among the jars, placing one in the first jar, one in the second, one in the third, another in the first, until there is an equal number in each jar.

Statistical Analysis:

These terms are often used by statisticians in describing the characteristics of quantities of data:

Mean—the same as average

Median—the middle number. For instance, if all the students in a class of 29 lined up in size places, the 15th child would have the median height.

Mode—the number that appears most frequently in a series. For instance, if a pulse rate of 80 was noted more frequently than any other number, 80 would be the mode. There can be more than one mode.

Range—the limit of variation in amount. For instance, the normal range of pulse rates for children between the ages of 8 and 15 is 60–110.

Surface-to-volume ratios:

The ratio of the surface area of an object compared to its volume is important in a variety of contexts. Food is chewed because making smaller pieces increases the surface area on which digestive juices can act. Bubbles are spherical because the soap film shrinks to the smallest surface area that can enclose the trapped air. Houses with many architectural projections are harder to heat and insulate than more compact houses. Crushed ice melts faster than block ice.

Similarly, people and animals that are small have a larger amount of surface area, relative to their volume; they can lose heat more readily; and their hearts have to beat faster to bring fuel to the cells.

The ratio of surface to volume can easily be illustrated using blocks. Have students use cubes to make different constructions and compare the number of blocks (volume) to their surface area (number of flat surfaces exposed to the outside). For instance, eight blocks arranged to form a 2 × 2 × 2 cube will have 24 units of outside surface area, a 24:8, or 3:1 ratio. Twenty-seven blocks arranged to make a 3 × 3 × 3 cube will have 54 units of outside surface area, a 54:27, or 2:1 ratio (distribute Diagram of Cubes, page 85).

Liquid Layering

Schools that implement the Standards will have students learning science by actively engaging in inquiries of interest and importance to them.
Draft, NRC Science Standards

Students should develop an understanding of properties of objects and materials.
Draft, NRC Science Standards

Overview: In this lesson, students are given four different "mystery liquids," droppers, a clear plastic straw, and a slice of potato to plug the end of the straw. Then they are given a challenge: to make layers of the four liquids in the straw. By predicting, then testing and revising their predictions, they gradually gather the data necessary to reach a solution. In the process, they develop valuable process skills and form a foundation for constructing the concept of liquid density. The lesson is adapted from "Layering the Unknown," the first of many excellent lessons in the guide, *Discovering Density*, published by Great Explorations in Math and Science (GEMS), Lawrence Hall of Science, University of California, Berkeley, CA 94720.

Problem: How can different-colored "mystery liquids" be layered in a clear plastic straw?

Materials:
For the class:
- ✓ 4 different food colors
- ✓ sharp knife for slicing potatoes
- ✓ kosher or pickling salt—5 tablespoons (You may substitute table salt, but the solution will be cloudy.)
- ✓ water—32 oz
- ✓ glycerin—16 oz.
- ✓ isopropyl or denatured alcohol—16 oz.
- ✓ 2 16-oz. jars
- ✓ 4 1-qt. wide-mouthed containers with caps
- ✓ 1 tablespoon
- ✓ measuring cup that will hold 2–3 cups
- ✓ medicine droppers—4 for each group
- ✓ copies of Data Sheet for Liquid Layering

For each group of 4–6 students:

- ✓ 6 clear plastic drinking straws
- ✓ a medium-sized raw potato
- ✓ 4 wide-mouthed clear plastic 9-oz. cups
- ✓ 4 medicine droppers
- ✓ 1 cup or other container to hold waste
- ✓ 2 or 3 paper towels
- ✓ crayons or markers (optional)
- ✓ 1 tray

Before class:

1. Prepare the four stock solutions:

Glycerin—add 25 drops of blue food coloring to 16 ounces of glycerin and shake well in a container. Test a drop in a straw to make sure it flows easily to the bottom. If it is too thick, add a little water until it is the consistency of syrup.

Salt water—Mix five tablespoons of kosher salt and 20–25 drops of green food coloring in 16 ounces of water. Shake well, making sure all the salt is dissolved.

Water—Thoroughly mix 20–25 drops of yellow food coloring with 16 ounces of water.

Alcohol—Thoroughly mix 30–35 drops of red food coloring with 16 ounces of alcohol.

2. Cut the straws in half. (Test to see that the diameter of the straw is large enough to permit the flow of liquids.)
3. Make one copy of the data sheet (see Recording Sheet, page 82) for each pair of students.
4. On the board, draw a diagram similar to that on the data sheet.
5. Organize the student materials for easy distribution. On each tray, put:

- ✓ 4 plastic cups
- ✓ 4 medicine droppers
- ✓ 2–3 slices of potato (Cut the potatoes shortly before class begins, so that they will not turn brown before class.)
- ✓ 4–6 straw halves
- ✓ 2–3 paper towels
- ✓ 1 waste container

✓ crayons or markers (optional)

6. On each tray, fill each of the four cups about one-quarter full with a different liquid. Place a medicine dropper in each cup.

7. Have extra materials on hand in a central location, in case of spills.

8. To avoid giving away part of the solution to the problem during the introductory demonstration, you may want to change one or more of the colors. One suggestion is to set up the following materials for your demonstration:

✓ a cup with a small amount of the red stock solution (alcohol), adding a few drops of blue food coloring to make purple
✓ a cup with a small amount of the green (salt water) solution
✓ 2 medicine droppers
✓ a straw half
✓ a slice of potato

Science teaching must involve students in inquiry-oriented investigations in which they interact with the teacher and peers.
Draft, NRC Science Standards

Safety Notes: Caution students not to taste any of the liquids.

GEMS also advises the use of the term "medicine droppers" instead of "eye droppers" to prevent children from thinking that they can put the liquids in their eyes.

Procedure:

1. Tell the students that they are going to be given a problem: They will try to make layers of different-colored liquids in a straw.

2. Model the procedure for placing the straw in the potato at a 45-degree angle, so that the potato can act as a plug for the straw. Show them the purple and green solutions, and demonstrate the procedure, using the medicine dropper to pick up some of the purple solution and drip it down the side of the straw.

3. Ask them what will happen if you add the green solution to the straw. Give students a chance to discuss their predictions, asking questions that begin with "Why do you think . . . ?" and "How do you know . . . ?"

4. Pick up some of the green solution in the dropper and drip it down the inside of the straw. It should sink to the bottom. Show students the results. (Putting white paper in back of the straw will help students to see the layers.)

5. Show students how to empty the contents of the straw by dumping it into the waste container.

6. Assign one person from each group to get the trays and bring them back to their tables.

7. Allow the students to practice with one of the liquids for a short time, to master the technique.

8. Distribute the data sheets, one for each pair of students, and describe the procedure for using them to make predictions and record data. The two partners should make a prediction, and record it by writing the letters, B, G, R, and Y in the appropriate order in the first diagram on the data sheet. They may also use the colored crayons or markers to record. Then they should test their predictions, and circle the combinations that worked according to their predictions. They should then make a revised prediction, record that in the same way, and continue testing and predicting, obtaining a little more information each time.

9. When a group has reached a solution, have them dump it out and try it again, layering the liquids in the expected order, to make sure there is a clear separation of liquids.

10. Ask students to draw and write about the results of their investigation, asking the question, "Why do you think that happened?" Any students who don't finish can complete the assignment for homework.

11. When all or most of the students have solved the problem, have them place the materials back on the tray, and have one person from each group take the tray back to the supply table.

12. Discuss the results with the class. Ask them to list the order of layering. Did all of the groups report the same results? Record the successful combinations on the blackboard diagram.

13. Ask the students why they think the layers formed as they did. Listen carefully to their explanations. Try to make sure that all students listen carefully to one another and participate in the discussion. Do not tell them what density is. The class in the video started out by thinking that color was the important factor, then adapted their thinking as students discussed other ideas. One student, not included in the video, said that he noticed that the darker colors rose to the top, and that the darker colors absorbed heat, and became lighter. This idea, although incorrect, demonstrated higher-level logical

LESSONS

Children, like scientists, will propose different explanations, and some children may have a need to establish whose ideas are good or best. Comparisons will come in time, when students are able to imagine ways to make judgments. Everyone's ideas should be valued, and differing opinions should be regarded as interesting and food for thought.
AAAS Benchmarks for Science Literacy

Substances have characteristic properties, such as density.
Draft, NRC Science Standards

thinking on the child's part. Finally, a student knew and described the word *density*, and the teacher was able to provide a demonstration that made sense to the class.

Background Information:

The term *density* describes the amount of matter in a particular volume of a substance. In common usage, we say that oil is "lighter" than water. However, an ocean of oil is not lighter than a cup of water. To be fair, we must use equal volumes for comparison. Densities are expressed in units such as grams per cubic centimeter (g/cc) or pounds per cubic foot. The density of water is 1 g/cc, or 62.4 lb./cu.ft.

Using Computers

Overview: This segment shows a class using computers to put together a multimedia presentation on whales. Programs like HyperCard, with utilities like HyperGasp, enable students to access information from a variety of sources, and put it together for a presentation.

The computer segment of the video, like all the other segments, shows some ways in which standards are being implemented in a school situation. Unlike the other segments, it not a model that can be replicated by all schools. Relatively few schools can now afford the kind of equipment pictured here. Even if they could, instructing participants on the technical aspects of using computers would be beyond the scope of the video and the *Facilitator's Guide*.

What the segment does reflect is *a philosophy for the future of computer education.* There are important points to consider, as school districts assess what they have, and look to the future. It is possible that the computers that already exist in the school can be used in more creative ways. It is also possible that school districts are planning to invest substantial amounts of money for computer education. Before they do, they must develop a vision that reflects the use of this investment and the existing hardware in ways that will best serve the needs of students in an information age. Will this sophisticated modern technology be used only to reinforce traditional teaching methods, or is there a greater potential to nurture creativity and higher-level thinking? We feel that the video brings out the following important points, that should be considered in planning for the maximum educational value from computers in the schools:

- Computers have the potential to develop higher-level thinking. Most commercial software emphasizes memorization and drill-and-practice techniques. Computers should be used to enable students to create, rather than absorb information. The students in the video used a variety of computer capabilities to gather and analyze data and make critical decisions as they synthesize the data to make their presentations.

- Scientific knowledge is advancing at a dizzying pace. Through the use of the Internet and CD-ROMs, computers are putting unprecedented amounts of up-to-date information at the fingertips of students. The world of the 21st century is destined to be an Information Age, in which people must deal responsibly and critically with tremendous amounts of information. Helping students use information wisely should be a high educational priority.

The primary job of a teacher is to promote learning, and so it follows that teachers themselves are dedicated learners.
Draft, NRC Science Standards

- The role and qualifications of the computer support teacher are vital. Beside having knowledge of computers, he or she should be a master teacher, one who understands the school curriculum and the learning process, one who is willing to invest the time and effort in designing programs that expand the regular curriculum and nurture the creativity and problem-solving skills of their students. Jerry Crisci, the computer teacher in the video, believes in using computer applications to enable students to design things. In one class, students used a database to design a zoo, so that animals from the same region can occupy the same habitat, and predators will not be housed with their prey. In another class, students use Logo to design three-dimensional snowflake designs. Still other students program commands to produce a pinball game which reinforces mathematical concepts of angles, multiplication, and greater-than and less-than variables.

- Classroom teachers themselves need to take advantage of every opportunity to learn new technologies, and to take the risk of allowing students to go beyond their own understanding. This is true not only of computer education, but of all teaching, particularly areas like science and computers, where knowledge is advancing so rapidly.

- Collaboration among teachers, administrators, community members, and the computer staff is vital, to ensure that the computer curriculum reflects appropriate content, skills, and the educational philosophy of the district. In Jerry Crisci's district, each school has a computer resource teacher, a classroom teacher responsible for coordinating the building's computer program.

- In planning their commitment to computer education, school districts need to be aware of the importance of support and staff development for teachers. Little is gained if money is spent on computer systems that teachers can't use, and software that reinforces traditional memorization and drill.

Multimedia Projects and Media Literacy—The benefits of students creating multimedia projects can affect a wide range of cognitive, psychological and academic skills that support an approach to learning that is multidimensional, rather than the strictly verbal, reading and writing formulas of the past. Students learn in different ways, not just from the written word. Using a multimedia approach challenges students to develop different cognitive abilities and perspectives.

Multimedia projects help children to be more active in front of the computer. Much of the danger of computers' adversely affecting children lies in the automatic processing of information without making the necessary mental effort. The language of multimedia is much like that of films and television, incorporating audio, video, graphics, still pictures, and music. This language is received by the mind differently from the written word. It communicates feeling more directly than print. When students begin to explore this language, they become more aware of its dynamics and how it influences the viewer. Thus, critical thinking capabilities are developed, not only in relation to computer programs, but also in regard to films and television viewing.

Educators need to recognize the influence of this language, which has the positive capability to enhance students' understanding of a subject. Through working with other students, students also become familiar with the creative process and how decisions are made creatively, thus increasing their self-confidence and self-esteem. By creating multimedia projects for their students, teachers are helping students to benefit from the technology that is increasingly becoming part of their lives, while developing more awareness of its potential negative aspects that foster passivity and lack of critical thinking.

Finding the Average Pulse Rate (Optional)

Counting pulse beats for one minute.

Use the index and middle finger of your right hand to find the pulse on the inside of your left wrist, pressing lightly just above the midpoint of the wrist.

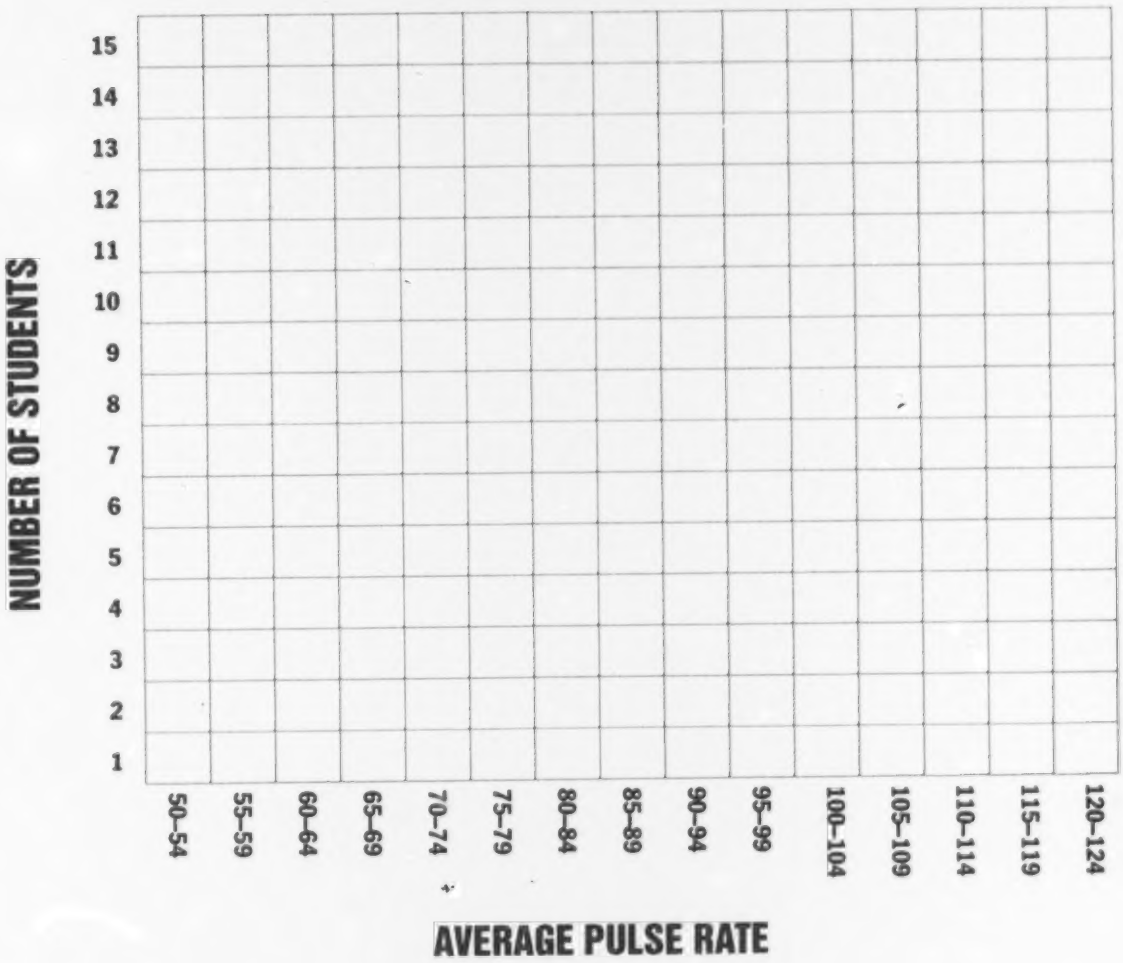
You should be seated and relaxed for this part of the activity. When the teacher gives the signal, start counting. When the teacher gives the signal to stop, write the number of pulse beats here.

My heartbeat rate is ____ beats per minute.

Next, you are going to count the number of pulse beats in 15 seconds, multiply by 4 to find the number of beats per minute, repeat this two more times, then find the average of the three readings.

Trial #	Beats per 15 sec	× 4 =	Beats per minute
1		× 4 =	
2		× 4 =	
3		× 4 =	
		Total	
		Divide by 3	÷ 3
		Average Resting Pulse Rate	

Distribution of Pulse Rates in Our Class



Comparing Pulse Rates

Find your average resting heartbeat as before, to get a base line for today's activities.

Trial #	Beats per 15 sec	× 4 =	Beats per minute
1		× 4 =	
2		× 4 =	
3		× 4 =	
		Total	
		Divide by 3	÷ 3
		Average Resting Pulse Rate	

Repeat the procedure while standing, after standing for one full minute.

Trial #	Beats per 15 sec	× 4 =	Beats per minute
1		× 4 =	
2		× 4 =	
3		× 4 =	
		Total	
		Divide by 3	÷ 3
		Average Standing Pulse Rate	

Optional—Repeat the procedure while lying down, after lying down for one full minute.

Trial #	Beats per 15 sec	× 4 =	Beats per minute
1		× 4 =	
2		× 4 =	
3		× 4 =	
		Total	
		Divide by 3	÷ 3
		Average Pulse Rate Lying Down	

Pulse Rates After Exercise
Recording Sheet

Instructions

You should be seated and relaxed for this part of the activity. Find your average pulse rate as before. Count the number of pulse beats in 15 seconds, multiply by 4 to find the number of beats per minute, repeat this two more times, then find the average of the three readings.

Trial #	Beats per 15 sec	× 4 = Beats per minute
1		× 4 =
2		× 4 =
3		× 4 =
		Total
		Divide by 3 ÷ 3
		Average Resting Pulse Rate

Within 15 seconds after exercise, return to the gathering area. When the teacher gives the signal, count your pulse for 15 seconds. The teacher will tell you when to stop counting. Record the count in the 0:00 space. Find your pulse again, and repeat the procedure until you are told to stop.

See the next page for recording sheet.

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Recording Sheet

Minute After Exercise	Pulses per 15 seconds	× 4	= Pulses Per Minute
0:00		× 4	=
0:30		× 4	=
1:00		× 4	=
1:30		× 4	=
2:00		× 4	=
2:30		× 4	=
3:00		× 4	=
3:30		× 4	=
4:00		× 4	=
4:30		× 4	=
5:00		× 4	=
5:30		× 4	=
6:00		× 4	=
6:30		× 4	=
7:00		× 4	=
7:30		× 4	=
8:00		× 4	=
8:30		× 4	=
9:00		× 4	=
9:30		× 4	=
10:00		× 4	=
10:30		× 4	=
11:00		× 4	=
11:30		× 4	=
12:00		× 4	=
12:30		× 4	=
13:00		× 4	=
13:30		× 4	=
14:00		× 4	=
14:30		× 4	=
15:00		× 4	=

Pulse Rates After Exercise

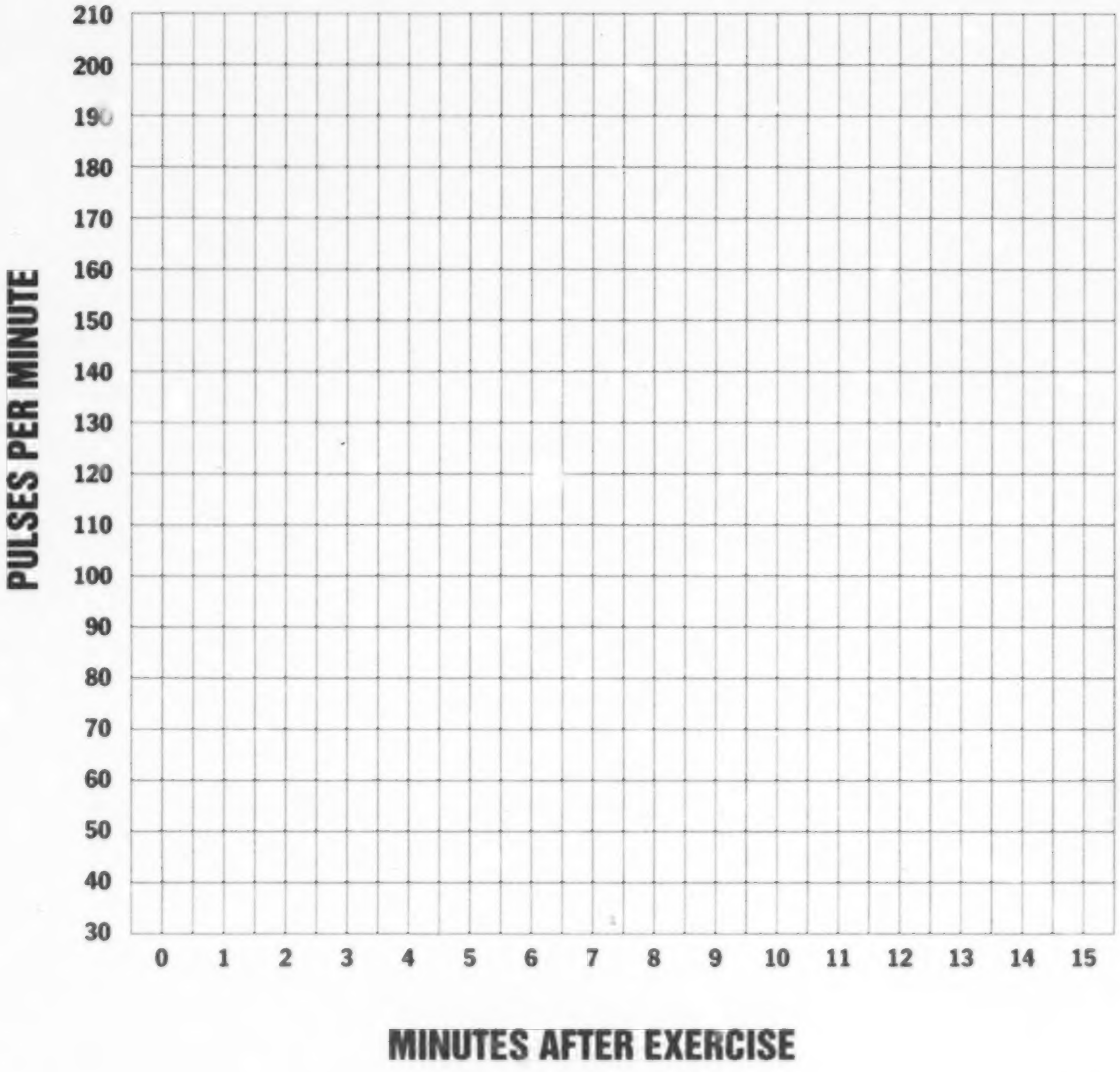
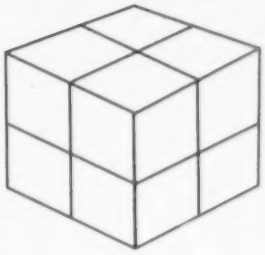
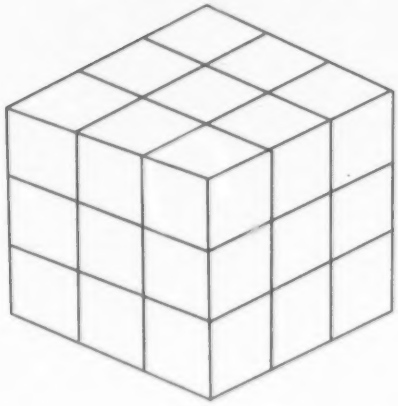


Diagram of Cubes

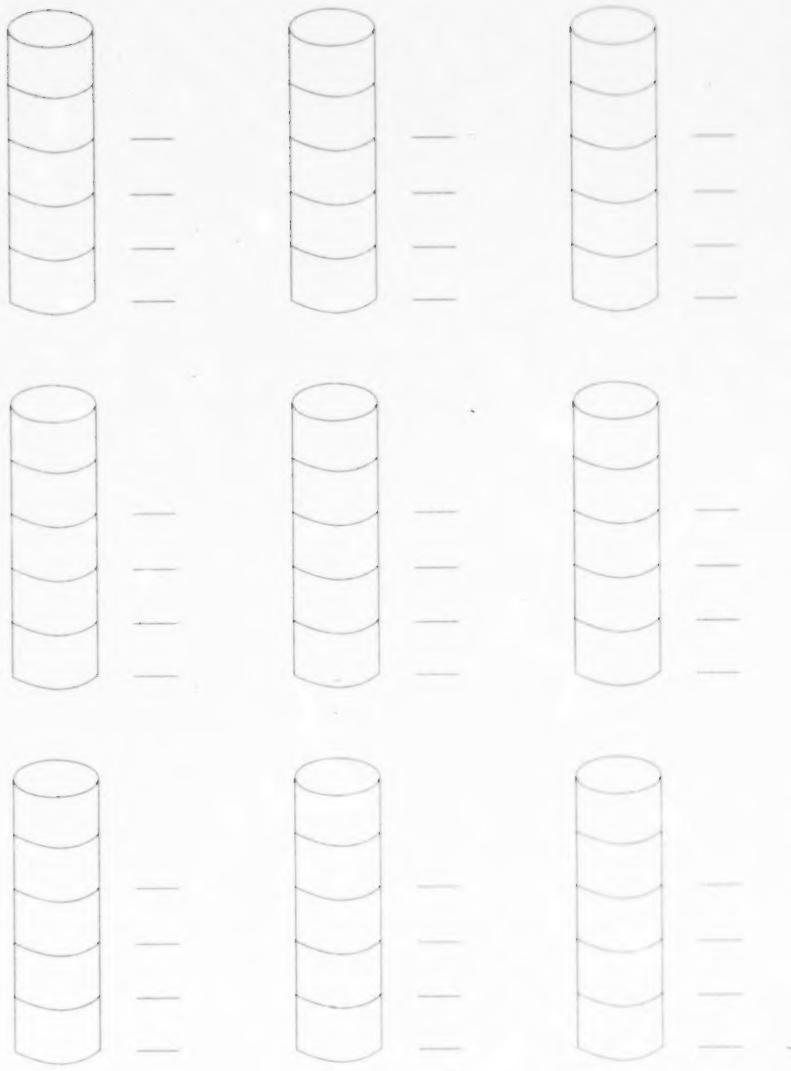
2 × 2 × 2 Cube



3 × 3 × 3 Cube



Data Sheet for Liquid Layering



Use this sheet to record and revise your predictions.
Write or color your first prediction in the first diagram.
Test your prediction.
Circle the combinations that layered according to your prediction.
Make a new prediction and write or color it in the next diagram.
Continue until you have solved the problem, then check your answer.

OVERHEADS

OVERHEAD 1

Objectives of the Workshop

At the end of this program, participants will be able to:

- **Explain the significance of documents such as the NRC Science Standards, AAAS Benchmarks, and science frameworks.**
- **Understand how to design a lesson that incorporates some of the science standards and demonstrates effective management of materials, questioning techniques, integration, and authentic assessment.**
- **Describe the role that elementary science plays in preparing students for life in a technological information age.**
- **Recognize the motivational value of hands-on science activities.**
- **Identify issues and concerns involved in implementing science standards.**
- **Develop a personal or group plan of action related to the science standards.**

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OVERHEAD 2

Finding the Average Pulse Rate (Optional)

Counting pulse beats for one minute.

Use the index and middle finger of your right hand to find the pulse on the inside of your left wrist, pressing lightly just above the midpoint of the wrist.

You should be seated and relaxed for this part of the activity. When the teacher gives the signal, start counting. When the teacher gives the signal to stop, write the number of pulse beats here.

My heartbeat rate is ____ beats per minute.

ASCD
Association for Supervision and Curriculum Development

Next, you are going to count the number of pulse beats in 15 seconds, multiply by 4 to find the number of beats per minute, repeat this two more times, then find the average of the three readings.

Trial #	Beats per 15 sec	× 4 =	Beats per minute
1		× 4 =	
2		× 4 =	
3		× 4 =	
			Total
			Divide by 3 ÷ 3
			Average Resting Pulse Rate

OVERHEAD 3

Graphing Average Pulse Rates

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OVERHEAD 4

Pulse Rates of Various Mammals

The heartbeat rates for some familiar mammals are:

mouse	1000
rabbit	140–160
cat	120–140
dog	70–120
lion	40–50
horse	30–45
cow	40–70
elephant	25–47

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OVERHEAD 5

Data Sheet for Liquid Layering

- Use this sheet to record and revise your predictions.
- Write or color your first prediction in the first diagram.
- Test your prediction.
- Circle the combinations that layered according to your prediction.
- Make a new prediction and write or color it in the next diagram.
- Continue until you have solved the problem, then check your answer.

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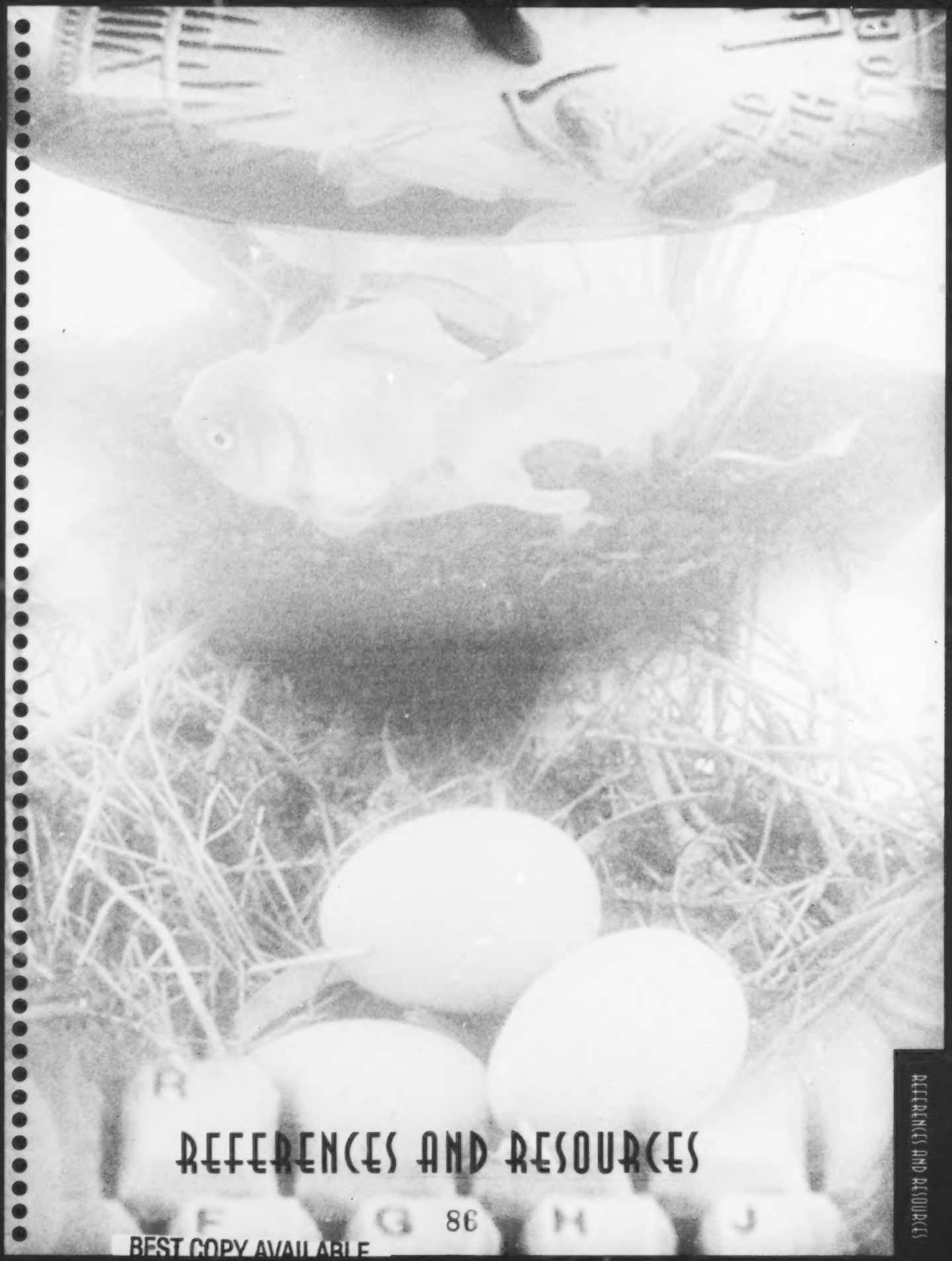

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BEST COPY AVAILABLE

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CURRICULUM
UPDATE

Reinventing Science Education

Reformers Promote Hands-On, Inquiry-Based Learning

BY SCOTT WILLIS

In Lisa Nyberg's classroom at Brattain Elementary School in Springfield, Ore., 3rd and 4th graders are learning about simple machines. The classroom is a flurry of activity, as children take apart broken toasters and other household appliances, trying to identify the simple machines within. Students examine and test the mechanical workings intently, discussing their ideas with their partners. A child disassembling a tape recorder forms the theory that pushing a certain button works a switch. Another child is consulting the resource books scattered around the room, searching the index of *How Things Work* for "vacuum cleaners." When the children discover inexplicable components—such as electrical circuits and computer chips—they are eager to learn more.

Across the country, in Michele Bartlett's earth science class at Rundlett Junior High School in Concord, N.H., 8th grade students are participating in an international ozone monitoring project. Using filter-paper badges, students collect smog data locally and then share their findings via the Internet with students at 80 other schools around the world. Bartlett's students also graph and analyze the data. In the process, they learn vocabulary such as "nitrous oxide" and "parts per billion" without having to resort to rote memorization. Students also submit their data to the Air Quality Board, the governor, and the National Student Research Center. Because they care about air quality, and because they are collecting real data to be shared with others, students take their work seriously.

LINDA ARMSTRONG

Giving students experiences with real phenomena is central to the reform agenda.

If these students had been born only a few years earlier, their experiences in learning science might have been starkly different. Science education has traditionally followed the "teaching by telling" approach. Teachers have relied heavily on textbooks and lectures to convey large quantities of information, and students have been expected to memorize reams of facts and terminology. Hands-on experiences have typically been limited to "cookbook labs" with outcomes known in advance, not real investigations. In most classrooms, science has been presented as an inert body of knowledge to be assimilated, rather than a process of inquiry and a way to make sense of our world.

The traditional "telling" approach has allowed science teachers to cover a great many topics. But the quality of student learning that it has yielded has proven disappointing, experts in the field say. Many students can parrot what they've been taught, but their understanding of science concepts is often seriously flawed. Students' prior misconceptions, for example, stubbornly resist change.

Even on standardized tests, which emphasize recall over reasoning, student achievement has been lackluster. According to the most recent data from the National Assessment of Educational Progress, "Compared to 1969–70, average [science] achievement in 1992 was higher at age 9, essentially the same at age 13, and lower at age 17."

Perhaps worse, the "telling" approach bores and alienates many students, who stop taking science courses as soon as possible. As a cohort of students progresses through high school, the number enrolled in science classes drops by roughly half each year, experts say. And the students who typically stick with science courses and succeed in them—students who are highly verbal and have good memories—do not necessarily make the best scientists.

Faced with these problems, the science education community is working zealously to reform itself. Major organizations—such as the National Science Foundation (NSF), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the National Academy of Sciences—are vigorously promoting the kinds of hands-on, inquiry-based activities described at the beginning of this article.

Reformers have set forth, in detail, a new vision for science education. Strong themes in the reform literature include the following:

- Learning of concepts should be emphasized over memorization of terms and facts.
- Students should have ample opportunities for hands-on learning. Concrete experiences with actual phenomena should precede more abstract lessons.
- Science instruction should be inquiry-based, at least in part. Students should have opportunities to pose their own questions, design and pursue their own investigations, analyze data, and present their findings.
- Teachers should explain concepts thoroughly before introducing the terminology associated with them, to ensure real understanding rather than parroting.
- Teachers should teach fewer concepts, in greater depth, rather than covering a great many topics superficially. ("Less is more.")

A Snapshot of the Field

How does science education play out on a day-to-day basis, in classrooms across the United States? Findings from the 1993 National Survey of Science and Mathematical Education, conducted by Horizon Research, Inc., with funding from the National Science Foundation, shed light on this question. The survey gathered data from approximately 6,000 U.S. teachers of math and science in grades 1–12 about their beliefs and practices. It also gathered data from department heads and lead teachers about their schools' science programs. Some illuminating findings follow.

Science Instruction

- Although use of hands-on activities has increased since the mid-1980s, science teachers still rely heavily on lectures and textbooks.
- The vast majority of science classes use one or more commercially published textbooks or programs, including 95 percent of middle and high school science classes. At the elementary level, 75 percent of science classes use published textbooks or programs, down from 86 percent in 1986.
- Looking across all science classes, the largest proportion of class time is devoted to lecture and discussion (38 percent), followed by hands-on or laboratory work (23 percent), individual seatwork (19 percent), and nonlaboratory small-group work (10 percent), with the remaining 10 percent of time spent on noninstructional activities.
- Sixty percent of high school science and math classes listen and take notes during presentations by the teacher on a daily basis; 94 percent do so at least once a week.
- More than 60 percent of high school science classes never take field trips, 54 percent never use computers, and 43 percent never work in class on science projects that last at least a week.

Teachers' Goals

- According to teacher reports, the most heavily emphasized objectives in science classes are learning basic science concepts (heavily emphasized in 83 percent of science classes overall), increasing awareness of the importance of science in daily life (77 percent), and developing problem-solving and inquiry skills (74 percent).
- Approximately 20 percent of science classes in each grade range put heavy emphasis on preparing students for standardized tests.
- Teachers in classes with high proportions of minority students are more likely than others to emphasize preparing students for standardized tests, and less likely to aim toward preparing students for further study in science and math.

Time Devoted to Science

- In elementary classes, an average of only about one-half hour per day is spent on science instruction. This figure has increased slightly over the past 15 years.
- Students are typically required to take two years of science in high school.

Diversity Issues

- Non-Asian minority students are particularly likely to "drop out" of science and math course taking.
- The proportion of science and math teachers who are themselves members of minority groups is very low—only about 11 percent in the elementary and middle grades and 7 percent at the high school level, at a time when roughly 30 percent of students belong to minority groups.

Equipment Needs

- Many science teachers indicated that certain kinds of equipment they need are unavailable. The most frequently cited needs were for running water, electrical outlets, gas for burners, and hoods or air hoses in laboratories, as well as videodiscs and CD-ROM players.

Adapted from *A Profile of Science and Mathematics Education in the United States: 1993*, by Iris Weiss of Horizon Research, Inc., 111 Cloister Court, Ste. 220, Chapel Hill, NC 27514-2296. ●

JOHN MCNAMARA

Hands-on approaches will attract a broader range of students to science courses, reformers believe.

- Students should have opportunities to *apply* science knowledge and to make connections between what they learn and their everyday lives.
- Teachers should build on students' prior understandings and prod them to rethink their misconceptions.
- All students should become science literate, not just the college-bound. Schools should prepare science-literate citizens, not just future scientists.
- Educators should begin to integrate the various science disciplines (biology, chemistry, physics), as well as integrating science with other subject areas.

The "overarching theme" of these reform ideas is constructivism, says Dennis Cheek, who coordinates mathematics, science, and technology for the Rhode Island department of education. The focus is on "allowing students to make meaning for themselves" through active learning experiences, rather than just barraging them with information.

These reform ideas are "absolutely vital," says Anthea Maton, a science education consultant from Oklahoma City. There's a big difference between teaching from the textbook and making sure students grasp concepts, she asserts. Students who only *know* the science they're learning and students who truly *understand* it are "poles apart."

Maton cites the example of a class she observed where a student incorrectly used the term *inertia* instead of *momentum*. If teachers introduce these terms without having students explore and discuss the associated concepts thoroughly, she says, students' understanding of the terms may be limited to "if something moves, it has it."

Inquiry-based learning yields deeper understanding because it focuses on the question "How do we know?" says Gerhard Salinger, a program director at the National Science Foundation. Although teachers can simply *tell* students facts—for example, that the earth has seasons because it rotates on a tilted axis—students will understand (and remember) such concepts better if they explore why we believe them to be true. Experimenting with a flashlight and tennis balls, he suggests, can help students truly understand what causes the seasons—and gives the teacher an opportunity to confront the misconception that, during winter, the entire earth moves farther from the sun.

These reform ideas are not new; experts in the field readily admit. Yet, from his visits to classrooms, Cheek has found "there's still an awful lot of 'chalk and talk' going on." Many teachers still place more emphasis on maintaining "control and quiet" than on using active, hands-on approaches that help students gain real understanding. Implementation of these ideas has a long way to go.

Major Reform Efforts

Several massive reform efforts are aimed at changing that situation. The National Science Foundation, for example, is funding statewide systemic initiatives to promote reform. Other high-profile efforts include NSTA's Scope, Sequence, and Coordination project, AAAS's Project 2061, and the new National Science Education Standards project.

Scope, Sequence and Coordination of Secondary School Science (SS&C) is a reform effort of the National Science Teachers Association (NSTA). SS&C recommends that all students study each science discipline—biology, chemistry, physics, earth and space science—every year for six years (in grades 7–12).

This approach is a radical change from the prevailing "layer-cake curriculum," in which students study earth science in 9th grade, biology in 10th grade, chemistry in 11th grade, and physics in 12th grade. (More than half of all students don't take a science course after 10th grade, and only 19 percent take a course in physics, according to NSTA literature.) The SS&C approach spreads out the study of each science discipline over several years. It also features hands-on, inquiry-based instruction.

When students study each science discipline beginning in the middle grades, courses like chemistry and physics don't seem so "foreign" to them when they are juniors and seniors, says Thomas Sachse, executive director of the California Science Project, a statewide staff development network. And because students learn these disciplines gradually, without complex math at first, they develop "an affinity, not a fear" for them, he adds.

SS&C is "trying to provide a substantial level of understanding [in each science discipline] for all students, in a society where people believe that most students can't learn it," says Bill Aldridge, NSTA's executive director. Most people, including science educators, sincerely believe that science at certain in-depth levels can't be learned by everyone, he charges. Yet the evidence against this belief—from countries that teach demanding science to a far greater proportion of students than the United States does—is "overwhelming," he says.

Typical science courses put "all the abstractions at the beginning" and emphasize the memorization of facts and processes—an approach that "basically sorts people out," Aldridge says. By contrast, SS&C modifies the curriculum in accordance with the research on how students learn. As a result, "essentially all kids can learn it."

Since 1990, SS&C has been implemented at the middle-school level at six pilot sites. Now, a newly launched study of 15 high schools implementing SS&C will "put it to the test," Aldridge says. He hopes the independent evaluation will show "dramatic" results, especially for minority students. Just showing a positive effect will not spur broad-scale change, he believes.

Project 2061, a long-term reform initiative of the American Association for the Advancement of Science (AAAS), addresses science, mathematics, and technology, says Jo Ellen Roseman, the Project's curriculum director. It focuses on the curriculum, because curriculum is "central to the reform effort." The Project's philosophy is set forth in two major publications, *Project 2061: Science for*

All Americans and *Benchmarks for Science Literacy*.

Science for All Americans, published in 1989, defines "a clear set of adult literacy goals in science, mathematics, and technology for everyone," Roseman explains. *Benchmarks for Scientific Literacy*, released in 1993, suggests concepts to introduce at grades 2, 5, 8, and 12 that would constitute "reasonable progress" toward the literacy goals. Where the benchmarks and the draft national standards for science education overlap (natural science and technology), they are "overwhelmingly the same," Roseman says, and thus mutually reinforcing. (For more on the national standards, see box, below.)

According to *Science for All Americans*, Project 2061 envisions a science curriculum in which

- the amount of detail that students are expected to retain is considerably less than in traditional courses, so that important concepts can be explored in some depth. Ideas and thinking skills are emphasized at the expense of specialized vocabulary and memorized procedures.
- boundaries between traditional subject-matter categories are softened and links are emphasized, so that students will appreciate connections among ideas.
- some topics rarely found in school curriculums are addressed, including the nature of the scientific enterprise, important episodes in the history of science and technology, and the major conceptual themes that run through almost all science thinking.

Project 2061 recognizes that curriculum reform is "necessary but far from sufficient" to transform science education, Roseman says. To support other aspects of reform, AAAS is producing computer disks of descriptions of recommended professional development resources and teaching materials. (The former will be available by

National Standards Seen as a Catalyst for Reform

Science, like many other subject areas, will soon have a set of national standards to bolster the efforts of reformers. Developed by the National Research Council (an agency of the National Academy of Sciences and the National Academy of Engineering), the *National Science Education Standards* have been widely disseminated in draft form. The final version is expected to be published this fall.

Unlike some similar efforts in other subject areas, the science standards take a systemic approach. Beyond spelling out important science content, they describe the kind of teaching, professional development, and assessment the field should provide. The draft document also includes "program standards"—criteria for judging school science programs—and "system standards," which address resources and coordination at the state and federal levels.

Not surprisingly, the science standards promote the major themes in the reform literature. The standards document states the following principles, among others, at the outset:

- All students should have the opportunity to attain higher levels of scientific literacy than they do currently.
- All students will learn all science in the content standards.
- All students will develop an understanding of science that enables them to use their knowledge in personal, social, and historical contexts.
- Learning science is an active process.
- For all students to understand more science, less emphasis must be given to some science content and more resources must be devoted to science education.

Development of the standards began in 1992, with broad input from scientists and science educators. The fourth and last round of review began in December 1994. Close to 40,000 copies of the draft document have been distributed, half to individuals and half to focus groups of teachers, professors, businesspeople, and scientists.

"I am relieved to say that most of the responses are very positive," reports Angelo Collins, director of the National Science Education Standards Project. One complaint some reviewers have made, however, is that the draft document is too long. "No one has suggested something to take out, though," Collins notes wryly. Other reviewers have criticized the standards for failing to capture adequately the *quantitative* aspect of science—a concern that will prompt some revisions, Collins says.

The content standards focus on fundamental concepts—the "big ideas" such as motion, force, matter, energy, evolution, and genetics—rather than bogging down in numerous topics, factoids, and technical words, says Rodger Bybee, who served as chair of the working group on science content standards. Bybee is associate director of the Biological Sciences Curriculum Study (BSCS).

The content standards also attempt to broaden science learning beyond a narrow focus on life, earth, and physical sciences, Bybee says. Therefore, they include several other categories as well: science and technology, science in personal and social perspectives, history and nature of science, unifying concepts and processes, and science as inquiry.

According to the standards document, inquiry "involves making observations, posing questions, examining books and other sources of information to see what is already known, planning investigations, reviewing what is already known in light of experimental evidence, proposing answers and explanations, and communicating the results."

The content standards represent fundamental concepts that *all* students should grasp, Bybee says. "We're focusing on the question, 'What should all citizens know and be able to do?' not 'What do students need to know to get into graduate school?' "

The standards are "silent" on the question of how the curriculum should be organized, Bybee points out. They do not pass judgment on the layer-cake curriculum, interdisciplinary approaches, or AP courses, for example. States and districts must determine what form the curriculum should take, he says.

Teaching Standards

Although the science standards also address teaching, they *don't* say, "This is the one way to teach," notes Karen Worth, who served as chair of the working group on science teaching standards. Worth is a senior associate at the Education Development Center and a faculty member in the graduate school of education at Wheelock College.

the end of this year; the latter, by late 1996, Roseman predicts.) Two other publications, *Designs for Science Literacy* and *Blueprints for Reform*, will help educators design K–12 science curriculums and pursue systemic reform, respectively.

What Teachers Need

The national science organizations are calling for reform, and teachers are listening. Do they like what they hear?

Teachers, as a group, have mixed feelings about the reform agenda (see box, p. 6). Those in the upper grades tend to be more resistant. The teachers interviewed for this article—all of whom have received Presidential Awards for Excellence in science—were enthusiastic about the reform ideas but described a variety of obstacles to implementing them.

To take a hands-on approach, teachers "constantly have to put together materials and activities," says Alfred Benbenek, who teaches 5th grade at Holt Elementary School in Whitman, Mass. Given small budgets for science materials, teachers have to "beg, borrow, and steal" materials such as cups, zip-lock bags, wires, batteries, and aluminum foil, he says. Because these things wear out, teachers are in constant need of them.

Teachers are eager to do hands-on activities, says Jane Carey, who teaches 2nd grade at Lancashire Elementary School in Wilmington, Del. Teachers are held back, however, by lack of direction about what to do, lack of materials (without scrounging), and lack of training, which makes them "hesitant to jump in."

Carey teaches a unit on "sinking and floating" in which students test a variety of objects to see whether they sink or float, then try to turn a "sinker" into a "floater" and vice versa. The class makes a chart of materials and their properties. Then students apply what

Because the standards promote science as inquiry, they ask teachers to help students become inquirers who learn basic concepts in the context of investigations. Worth acknowledges that this role will not appeal to all teachers. "There are teachers out there who still do not believe philosophically in teaching for understanding rather than [dispensing] information," she says. "If you're in the 'they-really-should-know-these-facts' camp, you won't want to do this." Teachers who want students to construct their own understandings, on the other hand, will find the standards "an important validation," she believes. These teachers "tend to be viewed as the fringe," she says. "Now they will be validated as the center."

The bottom-line message of the assessment standards is that educators should collect information about what students understand for a *variety* of purposes—not just to assign grades, says Audrey Champagne, who served as chair of the working group on science assessment standards. Champagne is a professor of chemistry and education at the University of Albany (SUNY).

The new emphasis on inquiry and reasoning skills poses a challenge for assessment, she notes. It's relatively easy to assess whether a student can use a balance to measure mass, for example—it's harder to assess whether the student can figure out that she *needs* to use a balance. Yet both kinds of abilities are important to assess.

Nothing New?

"To some degree, you could say there's nothing new in the standards," says Harold Pratt, who worked on the standards development team for more than two years. A former director of curriculum in Jefferson County, Colo., Pratt now directs an elementary science program for BSCS. The ideas reflected in the standards have been widely accepted in the field for many years, Pratt maintains. Yet "they are far from being implemented," he says. Implementation has been "our Waterloo."

The standards should be neither slavishly followed nor dismissed out of hand, Worth says. "This is not a perfect document, and it should not be followed perfectly—but it should be seriously considered."

The response of many teachers to the standards, however, is "You must be kidding," Worth concedes. Teachers' resistance is not so much a reaction to the philosophy embodied in the standards as to the fact that assessments and resources are not yet aligned with that philosophy. Even some teachers who fully endorse the standards say, "I'm not going to touch these until the rest of the world agrees and provides the resources we need for implementation." Worth calls this attitude "a well-founded cynicism."

Educators should not expect that teachers will pick up the standards and use them directly, Pratt says. "This is not a document that tells you what to do in your classroom tomorrow." The standards are "not a how-to document," Worth agrees. Instead, they are "a guide for decision making"—a set of criteria against which to weigh policy decisions, from the school level to the national level.

Perhaps unfortunately, the scope of the national standards does not, for the most part, extend to higher education, Pratt notes. "That piece is yet to be done—and it's an important part of the system."

The standards are one strategy for moving reform forward—not a panacea, Pratt says. But they will serve as "a catalyst for improvement," he believes. "They will focus our attention." Science educators should get acquainted with the standards and use them as a focus of dialogue and discussion, he advises.

Although the standards document is only in draft form, "the signs are that it's already had a big impact," Collins says. The standards are exerting an influence on state curriculum frameworks, textbook publishers, and professional development offerings, she says. The major organizations in science education are all promoting their implementation, she adds. For example, NSTA has already published *A High School Framework for National Science Education Standards* to help educators create programs based on the standards.

"The harder task lies before us," Bybee cautions. "It was relatively easy to develop the standards. But translating them into programs to help all students achieve higher levels of scientific literacy will be a tremendous task," he says. The "scaling up" will require a concerted, national effort. States and districts will have to devote resources to the endeavor, as will the U.S. Department of Education, the National Science Foundation, organizations such as NASA, and private foundations. "It's their move now." ●

The final version of the standards, anticipated next fall, will be sold by National Academy Press. For more information, contact the National Science Education Standards Project, 2101 Constitution Ave., N.W., HA 486, Washington, DC 20418; (tel.) 202-334-1399.

they've learned by creating a classroom aquarium. "If teachers had the time and resources," more ideas like this would flourish, Carey says.

Judy Morlan, who teaches 6th grade at Brownell Middle School in Grosse Pointe Farms, Mich., finds it "very difficult" to put constructivist principles into practice in her science teaching. She is frustrated by "a tightly packed curriculum" that she is held closely to. Because she must cover all the objectives, Morlan can't take the time to teach certain topics in depth, as she would like to do. In addition, trying to identify the misconceptions of a classful of children, and then working to change them, is very time-consuming.

"I feel like I'm in the middle," she says, because she is forced to compromise. "I'm a part-way person."

Morlan uses active learning "to make an impression on kids with the important things." For example, she has her students pace out the relative distance of the planets from the sun. "They respond to this sort of thing," she reports. She feels her efforts have been worthwhile when, for instance, a student exclaims, "Oh, my gosh—I didn't realize Pluto was *that* far from the sun!"

High school teachers are reluctant to change because they still feel accountable to colleges and universities, says Margo Murphy, who teaches 9th-grade environmental science at Georges Valley High School in Thomaston, Maine. Although Murphy herself doesn't teach from a textbook, most high school science is textbook-driven, she says. To create another kind of course demands "an enormous amount of work" from a teacher. It takes "a huge amount of time to convert" to an inquiry-based approach, she says.

Naturally, given these challenges, reformers are calling for more professional development for teachers of science. Teacher training is a big component of reform proposals, says Maton. "Nobody is advocating just *telling* teachers to teach this way."

Reform should *focus* on teacher education—both preservice and inservice, says Marvin Druger, chair of science teaching at Syracuse University and president of NSTA. "That's where the action should be." Many reformers are urging that undergraduate science courses become inquiry-based as well. Future teachers who have learned science in 300-seat lecture halls will not know how to foster active learning, they assert.

Teachers' Attitudes Toward Reform

Do teachers embrace the reforms in science education that national organizations are advocating? The 1993 National Survey of Science and Mathematical Education provides some insights. Conducted by Horizon Research, Inc., with funding from the National Science Foundation, the survey asked approximately 6,000 U.S. teachers of math and science in grades 1–12 about their training, pedagogical beliefs, and instructional practices. Here are some highlights from the findings:

Teachers Support Some Reform Ideas . . .

- Nearly all teachers believe hands-on activities should be part of science instruction.
- Most teachers believe that science instruction should provide students with concrete experiences before exposing them to abstract treatments. About 84 percent of high school teachers, and more than 90 percent of teachers at other levels, hold this view.
- Most teachers believe that students learn best when they study science in the context of personal or social applications. More than 90 percent of teachers at the elementary and middle school levels hold this view, as do 86 percent of teachers at the high school level.
- Most teachers support the use of cooperative learning in science classes. More than 80 percent of teachers at the high school level, and more than 90 percent of teachers at other levels, hold this view.

. . . But Resist Others

- Teachers are divided on the idea of emphasizing "depth over breadth." Only about 70 percent of elementary and middle grade teachers, and fewer than 60 percent of high school teachers, agree that science and math instruction should provide deeper coverage of fewer concepts.
- Many teachers resist the advice of reformers to teach science concepts *before* teaching the terminology associated with those concepts. Nearly one-third of teachers in grades 1–4, increasing to more than half of high school science teachers, indicated that "it is important for students to learn basic scientific terms and formulas before learning underlying concepts and principles."
- Although the reform literature calls for de-emphasizing factual learning in science, many teachers report that they emphasize this objective in science classes. Half of elementary science classes, and nearly 2 out of 3 in the middle and high school grades, put heavy emphasis on learning "important terms and facts in science."
- Many teachers doubt that heterogeneous grouping is the way to ensure success for all students. Roughly 3 in 10 teachers of grades 1–4 believe that students learn science and math best when grouped with peers of similar abilities. At the high school level, more than 7 out of 10 teachers hold this view.
- Although reform advocates tend to be critical of science textbooks, most science teachers are pleased with the quality of their textbooks. About 3 out of 4 teachers rate their science textbooks "good" or better.

Attitudes Differ by Grade Level

- Elementary teachers tend to be confident in their ability to use reform-oriented strategies such as cooperative learning. However, many do not feel confident in their ability to teach a number of elementary science content areas.
- High school teachers are more likely to have extensive preparation in their subjects, but they are less supportive of reform-oriented teaching techniques, less confident in their ability to use them, and less likely to do so in their classrooms.

Adapted from *A Profile of Science and Mathematics Education in the United States: 1993*, by Iris Weiss of Horizon Research, Inc., 111 Cloister Court, Ste. 220, Chapel Hill, NC 27514-2296. ●

Science courses have been too abstract and too mathematical from the outset, reformers charge.

JOHN MCNAMARA

In the reform literature, "textbook-driven" has become a pejorative term. Reformers of science education have criticized textbooks for abetting the "teaching by telling" approach.

Science texts in the United States differ from those used in other countries, says Senta Raizen, director of the National Center for Improving Science Education. U.S. textbooks "treat many topics in a scattershot fashion," whereas those in other countries treat fewer topics, in greater depth, and include far less review.

But U.S. texts are beginning to change, Raizen says. Textbook publishers try to follow state guidelines, she notes. "They're not nasties." But they can't prescribe how motivated teachers will be to encourage students' own investigations rather than lecturing from the textbook, she adds.

One 11th-grade textbook that anticipated the reform movement is *Chemistry in the Community*, developed in 1982 by the American Chemical Society. Now in its third edition, the book is "still considered rather nouveau," says Sylvia Ware, director of the Society's education division.

Chemistry in the Community was designed to correct the "mismatch" between chemistry instruction and students, Ware says. Most high-school chemistry serves best as an introduction for those who intend to earn a bachelor's degree in the subject—"but of course most students won't do this," she points out. Instruction is too abstract and too mathematical, Ware charges. "Chemistry doesn't have to be a quantitative discipline from Day One."

Unlike a traditional text, *Chemistry in the Community* examines issues in the community, to teach "chemistry for citizenship." The book is designed around eight issues: water needs, conserving chemical resources, petroleum, food, nuclear issues, air, health, and industry and its role in society.

Students using the text make lots of decisions and apply chemical knowledge, Ware says. In the first unit, for example, a scenario describes a "fish kill" in an imaginary river. Students investigate why the fish died, then hold a town meeting, where the facts come out. Then they must decide how to handle the problem.

"We're trying to rehabilitate the utilitarian," Ware says. "Knowledge can be useful—that's not a negative! If knowledge were only abstract, we'd never have got out of caves," she jokes.

Going Too Far?

Despite widespread enthusiasm for reform, some science educators fear that reform ideas may be taken to extremes.

"There seems to be a [misconception] that all science at all grade levels should be learned through inquiry," says Audrey Champagne, a professor of chemistry and education at the University of Albany (SUNY). Champagne finds this view too one-sided. In the early grades, inquiry-based learning can help students develop knowledge and reasoning skills that will enable them to learn in more traditional ways ("book learning") in the upper grades, she believes.

The heavy emphasis on inquiry may be an overreaction to the current overemphasis on facts, Champagne says. "Education in the United States is characterized by pendulum swings to the extreme."

Inquiry-based instruction is "a good idea in moderation," says David Haury, director of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education. As students, "we all benefit from a *mixture* of experiences."

In today's climate of reform, there is a readiness to denigrate textbooks and lectures, Haury says. But when students' curiosity is aroused, they are receptive to reading or listening. And if students are to become science literate in 12 years of schooling, "some things must be told to them." Therefore, teachers should seek a "happy balance," Haury advises. "You don't have to throw away one [approach] to do the other."

Haury also has concerns about the "less is more" philosophy. Teachers embrace the idea, he says, but they are uncomfortable with having to defend the practice. Teachers are placed in an awkward position when they must respond to administrators or parents who ask, "Why aren't you teaching this formula or that set of facts?"

Paring down the curriculum in keeping with the "less is more" philosophy ought *not* to be done on an individual-teacher basis, says Carolee Matsumoto of the Education Development Center. It's "risky" for teachers to take a stand on their own; they are too vulnerable to attack. Instead, the school or district should develop a scope and sequence with input from science experts, teachers, parents, and others, she says.

Some science teachers are uncomfortable with the notion of de-emphasizing facts and terms. Paul Pomeroy, who teaches 12th-grade physics at Archmere Academy in Claymont, Del., believes the reform ideas are "incredibly good in many ways." But he also thinks the heavy emphasis on teaching concepts is "a misguided notion." What started as a push to *include* hands-on activities and opportunities to conceptualize is being "misconstrued by many as the only good way to teach science," he says.

Pomeroy agrees with reformers that "memorizing and spitting stuff back is horrible science." But students still need to know

terms, facts, and how to compute, he says. And "there are times you have to get into the theory and muck through it."

College-bound students still need to develop the skill to "regurgitate" information, says C. Ford Morishita, who teaches biology at Clackamas High School in Milwaukie, Ore. Teachers of Advanced Placement (AP) courses *must* emphasize coverage and teach prescribed labs, he adds. "You can't cut content or you're cutting students' throats on AP exams."

Raizen also advocates using a mix of instructional strategies. "I'm someone who wants to make sure we don't throw out older styles of teaching," she says. However, most classes are still textbook- and lecture-oriented, she points out. "We're far from having the pendulum swing too far—yet."

The reform notion of extending science instruction to a much broader range of students also raises concerns.

Schools can't teach just a "literacy curriculum," says Morishita. "Bright kids need another level of opportunity." He worries that schools might phase out advanced single-discipline science classes and research opportunities. "We can't do 'science for all' at the expense of the high achievers," he says.

Pomeroy also fears that "in making sure every student gets some science, we may sell the top third of students short," by "diminishing the intensity" of their instruction. He is disturbed by the prevalent attitude that bright students will thrive, regardless of their school experiences. "A good student needs to be pushed too—and farther," he says.

"Science for all" is the subject of "a raging argument," Salinger of NSF says. One way of teaching that challenges *all* students—even "the really bright kids"—is to pose open-ended "design problems," he says. For example, a teacher could ask students to design a container to get a baked potato home hot from a fast-food restaurant. This problem requires students to set a standard for what "hot" is, measure the thermoconductivity of various materials, consider structural rigidity, and address environmental concerns. Different students could be encouraged to design their solutions under different sets of constraints, depending on their ability, Salinger adds.

Moving Beyond Experience

The reform movement in science education is promoting many very good ideas that make logical sense, Haury says. But how do educators actually put them into practice? "None of us have experienced it," he says of the new vision of active learning. "Trying to get large communities of people to think beyond the boundaries of their own experience—that's the challenge." ●

Resources

The following organizations can provide resources for improving science education.

American Association for the Advancement of Science, 1333 H St., N.W., Washington, DC 20005; (tel.) 202-326-6666; (fax) 202-842-5196.

National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000; (tel.) 703-243-7100; (fax) 703-243-7177.

ERIC Clearinghouse for Science, Mathematics, and Environmental Education, The Ohio State University, ERIC/CSMEE, 1929 Kenny Rd., Columbus, OH 43210-1080; (tel.) 614-292-6717.

National Science Resources Center, Arts and Industries Bldg., Room 1201, Smithsonian Institution, Washington, DC 20560; (tel.) 202-357-2555; (fax) 202-786-2028. The NSRC collects and disseminates information about exemplary teaching resources, develops innovative curriculum materials, and sponsors outreach activities to help school districts develop and sustain hands-on science programs.

Eisenhower National Clearinghouse for Mathematics and Science Education, The Ohio State University, 1929 Kenny Rd., Columbus, OH 43210-1079; (tel.) 614-292-7784; E-mail: info@enc.org. The Clearinghouse maintains an up-to-date and comprehensive listing of mathematics and science curriculum materials.

National Association for Science, Technology, and Society (STS), Pennsylvania State University, 133 Willard Bldg., University Park, PA 16802; (tel.) 814-865-3044; (fax) 814-865-3047. NASTS promotes examination of the impact of science and technology on society and the environment.

National Center for Improving Science Education, 2000 L St., N.W., Ste. 603, Washington, DC 20036; (tel.) 202-467-0652; (fax) 202-467-0659; BITNET: sentar@gwuvm.gwu.edu. NCISE provides a range of products and services to policymakers and practitioners who are working to strengthen science education.

Biological Sciences Curriculum Study, Pike's Peak Research Park, 5415 Mark Dabling Blvd., Colorado Springs, CO 80918; (tel.) 719-531-5550. BSCS is a nonprofit organization that designs curriculums in the sciences.

Education Development Center, 55 Chapel St., Newton, MA 02158; (tel.) 617-969-7100. EDC is a nonprofit organization that does research and development work in education, including curriculum development. ●

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Student-Centered Inquiry

Ramon E. Lopez and Jan Tuomi

A national consensus is evolving around what constitutes effective science education. It is reflected in an array of publications, including *Science for All Americans* (1989), *Benchmarks for Scientific Literacy* (1993), and *National Science Education Standards* (1994). These documents share two common convictions: (1) all students, and especially underrepresented groups (Oakes 1990), need to learn scientific skills, such as observation and analysis; and (2) these skills should be imparted in a "less is more" curriculum that begins in elementary school before kids form negative attitudes toward science.

As any scientist knows, the best way to learn science is to do science. This is the only way to get beyond dry facts to the real business of science—asking questions, conducting experiments, collecting data, and looking for answers. In elementary school, the best way to accomplish this is to examine natural phenomena that are brought into the classroom and studied over time. Active, hands-on, student-centered inquiry, in which kids learn to apply scientific problem solving, should be at the core of science education.

Elements of Success

With new materials available, a better understanding of how to do things, and a national consensus that reform is critical to our future, many school districts have begun to reform their elementary science programs systemically, that is, to revamp all elements of the system and institutionalize the changes. What does this entail? Four basic components:

1. Good teaching materials. These should be research-based, developmentally appropriate, designed by educators and knowledgeable scientists, and thoroughly field-tested. They should enable children to conduct long-term investigations (say, eight weeks), not with a series of single-shot activities, but with activities that build upon one another. The activities should encourage inquiry, address a variety of learning styles, and connect to other parts of the curriculum.

Excellent examples of such materials are found in *Science and Technology for Children* (Carolina Biological), *Insights* (Optical Data), and the *Full Option Science System* (Britannica). As for costs, it is often no more expensive to maintain a hands-on science program than a textbook program. Schools should use their resources to buy the best curriculum for their needs, knowing that teachers may develop additions or modifications after some experience with the units.

2. A materials support system. Because teachers do not have time to gather the needed materials, a science kit should arrive at a specified time with the materials the entire class needs for several weeks. When the unit ends, the kit can be picked up, refurbished at a central location, and sent to the next scheduled teacher.

3. A vigorous and ongoing professional development program. Teachers need to work through the units themselves and learn how to teach them. They need to be able to ask questions—particularly about classroom management—of more experienced teachers. They may also need support to overcome their fear of science and to realize that they, too, can become scientists. Administrators also need to experience what hands-on science is all about in order to support and evaluate an innovative program. Both need to understand that the statement "I don't know, but maybe we can find out" is the starting point for all inquiry.

4. New assessment tools. A bad standardized test can cause teachers and administrators to resist a good hands-on program. Performance-based testing and portfolios are preferable. Teachers may need inservices in the new assessment techniques, and parents and school boards will have to be kept abreast of the changes in grading.

To implement and sustain such a program, one needs to build community and administrative support and maintain it.

No New Discovery

The idea of hands-on science is not new. In the 1960s and early '70s, the National Science Foundation supported the development of hands-on teaching materials, such as the kits developed in the Elementary Science Study program and the Science Curriculum Improvement Study. Research showed that these materials were better at teaching science concepts and skills than were traditional textbooks. Well-designed materials also allowed all children to experience success in science, including kids who are good artists or communicators or who have superior hand-eye coordination.

Why, then, didn't these programs become the core of instruction? Partly because in most places, these kits were simply turned over to teachers who had little or no idea of how to use them effectively. Because elementary teachers generally have an inadequate science background, they naturally felt uncomfortable with the materials. Student inquiry meant a lot of noise and mess; materials didn't work right or were used up. What's more,

Lopez, R., and J. Tuomi. (May 1995). "Student-Centered Inquiry." *Educational Leadership* 52, 8: 78–79.

teachers feared that if they didn't cover all the material in the textbooks, their school's scores on the standardized tests would go down. And how do you grade kids for hands-on science anyway?

To this day, in school science closets and basements around the country, old science kits can be found with half the stuff broken or missing, or still in the shrink wrap because teachers were too intimidated to open them.

Finally: Breakthroughs

Not everyone shrank from the problems. Many educators found ways to refurbish the kits and buy replacement parts in bulk, to train teachers, and to grade hands-on science. In 1985, Doug Lapp, an elementary science program designer, founded the National Science Resources Center as a joint organization of the National Academy of Sciences and the Smithsonian Institution. The center, based in Washington, D.C., collected information about schools that had managed to sustain hands-on science programs for years or, sometimes, decades. The center then conveyed that information to other school districts.

About the same time the National Science Foundation began to fund curriculum development for a new generation of kit-based materials. These materials have gone through a rigorous research and development cycle, incorporating the best of earlier programs. They also have benefited from subsequent research in developmental psychology.

Such reforms in science education have been far-reaching. In the many communities that have succeeded in their reform efforts, scientists and engineers, as well as scientific and technical corporations, universities, national laboratories, and science museums have played critical roles. They have generated public awareness and support, and assisted with professional development and fund-raising.

The bottom line is this: We know what works for kids, we have a pretty good idea how to make it work in schools, and the help is out there to make it happen. ■

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PCS May Be Teaching Kids the Wrong Lessons

BY LAURIE HAYS

Staff Reporter of the Wall Street Journal

Sarah Kahn sees it as the battle of the screens.

In the family room of her New Canaan, Conn., home, three of her children flit from the TV set to the Game Boy to the PC and back again. "I say, 'Turn that TV off.' They go right to the next screen," says Dr. Kahn, a gastroenterologist. "The PC has the same pull as the TV."

Many parents think it's great when their kids flip on the computer, figuring that computers are educational and, at the least, less passive than television. "But here's the bad news: Most educational software isn't, alas, all that educational, and it can have many of the same ill effects as the boob tube."

Certainly PCS have great potential for promoting learning and creativity. Kids with short attention spans or those in need of remedial help can benefit from the lively graphics, sound and novelty of drill programs. Even if a program isn't perfect, when children and parents play it together, the kids get some benefit. And, after all, learning how to use a computer is good preparation for the future.

But PCS can also promote passivity, dull creativity and limit socialization in children, taking away from more important kinds of play, educational experts say. In some circles, fears are growing that a new generation bred in the "pop" PC world will suffer the same effects as the so called TV generation, with some kids emerging unable to reason well or communicate effectively.

"PCS, for the most part, are a debased form of play. It isn't the kind of imaginative play that young kids will indulge in if allowed to use their own resources," says Marie Winn, who in 1977 wrote "The Plug-In Drug," a book on the impact of television on children.

Some education experts believe fully 75% of the hundreds of software titles aimed at children don't teach much at all. Kids aren't "learning" as much as drilling by pointing and clicking. The ideas come from the software rather than the children, who respond by rote rather than by using their own thought processes.

Part of the problem is that even noncomputerized drill work is sharply at odds with "whole language," a popular educational approach that teachers children academic skills through an integrated curriculum.

But even some kids are critical. Eleven-year-old Jessica Djilani fooled around with drill programs at home in Scarsdale, N.Y., but found herself "just sitting there like a vegetable. It's like watching TV. You feel disgusting," she says.

Pat Aufderheide, associate professor of communications at American University, limits TV time for her six-year-old son and four-year-old daughter and is astonished by how "engaged and interested they are in computer games. After her son told her, "This is almost like TV," she realized how addicted he had become and began limiting his PC time, too.

Software makers call their wares "drill for skill," but some doubters prefer "drill and kill" because so many of the titles adopt shoot-em-up game techniques. This simplistic approach requires little direct help from mom and dad.

But that's the point, critics say. "Publishers want something that's easy to run, will catch the child's fancy and doesn't require parental assistance—because that's what will sell," says June Wright, a professor of early childhood education at Eastern Connecticut State University. Adds Joseph Parness, a developer of multimedia titles for Jostens Learning Co., "The majority of educational titles continue to prove to be nothing more than whimsical 'edutainment' products that have evolved into the fast foods of learning."

Reader Rabbit, an enormously popular series, is a frequent target of critics. Published by Learning Co., it has sold more than two million copies since it was first released in 1984, and last year it led the half-billion-dollar-a-year education market. In one of the programs, Reader Rabbit's interactive Reading Journey, a cartoon hare guides preschoolers and older kids through a series of games, sounding out words and hopping through books as children point and click.

All this looks educational, and many children love it. So do parents. Cheryl Truett of Canton, Ohio, says her six-year-old daughter, Shannon, a kindergartner, spends hours on Reader Rabbit and has taught herself to read. Mrs. Truett also finds the PC's electronic baby-sitting role convenient. It gives her time to do housework when Shannon is home in the mornings.

But a recent study of 49 children in Missouri found that those who used Reader Rabbit and similar drill programs for six months at their preschool had a 50% drop in creativity, as

measured by a standardized test, with no statistically significant gains in learning how to read.

The problem is that when words are taught as isolated objects they don't have real meaning, says Susan Haugland, the child-development professor at Southeast Missouri State University who ran the study.

In addition, her study found, children frequently play these games by randomly clicking on words until they find the right ones or memorizing the story, making it seem as though they are reading. Kids also tend to gravitate toward the least educationally useful aspects of a program when left to navigate it on their own.

The study also cited a discouraging addiction factor: Children using these programs, bent on competing to "win," were glued to the screen three times as long as those who used "developmental" software that was less game-like.

While some parents say they don't see the harm, Dr. Haugland opposes using such sophisticated, expensive gear to do the same flash-card job that a piece of paper and pencil can do.

Pat Walkington, vice president at Learning Co., defends Reader Rabbit: "I wouldn't say that it's better than a teacher or a parent, but it's very effective and engaging." A company spokeswoman adds that it beats violent computer games. "It does enhance learning—would you rather have them playing Doom?"

Math is another problem area. At Dr. Kahn's home, the two boys, Sam and Jake, are engaged in a prebedtime game of Math Blaster. The putative point of the game is to practice adding, subtracting and multiplying. But Jake, six years old, says he sees the object as "we get to shoot down spaceships." Nine-year-old Sam likes playing the program, too, but his mother says it's way too simple for him—"a waste of time."

Many educators say they believe children need to learn how to think through math problems rather than simply memorizing a list of answers. Yet "a steady diet of these programs makes you want to memorize and get the right answers," says Douglas Clements, a professor of math education at the State University of New York's Buffalo campus. What's more, after all the multimedia gizmos and games, kids may balk at doing math the boring, old-fashioned way, with pencil and paper.

Social interaction is also lost in most PC play. When children play together or with adults, discussions and disagreements ensue, teaching them to get along and see other points of view, experts say. Alone at the PC that doesn't happen.

Some experts say children can also lose a sense of empowerment with most PC software. Popular titles offer a predetermined set of options, automatically limiting a child's imagination. In small doses, this is probably fine, the experts say, but most children would still be better off sitting down with crayons and paper and making their own pictures or stories—or even, occasionally, doing nothing at all.

When kids play an old board game, they make up their own rules as they go along, notes Ms.Winn, the "Plug-In Drug" author. "Creating their own images helps children work out problems and resolve powerlessness," she says. "On the computer, the machine has all the power to make the rules."

Some Software Nurtures Creativity

BY LAURIE HAYS

Staff Reporter of the Wall Street Journal

For those who believe computers have potential for teaching, there is hope.

At the Edgewood School in Scarsdale, N.Y., 14 fifth-graders sit in pairs in a spacious, brightly lit computer classroom, working on Macintoshes. Using concepts from math class—angles, multiplication, greater-than and less-than variables—they have designed on-screen pinball games and are now testing them.

The projects are a team effort. Jessica, age 11, and Tom, 10, argued at length before finally agreeing to create a soccer game. Each movement required a command, which the children programmed themselves. Their ball now ricochets at a 170-degree angle because, after much trial and error, that angle "looked the most realistic," Jessica says.

The children are pleased with their results, which took them about six hours. "It's my favorite part of the day," Jessica says of computer class. "Both of us hate math, but math on the computer is fun. We look at what we've done and say, 'Aren't we smart.'"

Gerald Crisci, the school district's elementary school computer coordinator, says children should use computers to apply what they have learned to "do" and "make" things. That's why he recommends that kids wait to use computers until they reach the third grade and can apply basic skills. "Computers shouldn't be used for feeding kids information," he adds.

Mr. Crisci has third-graders create snowflakes in 3–D. The fourth-graders are putting together and programming animated zoos, drawing on their study of endangered species in science. Students have to remember fine points, he says, such as the need to avoid putting predators and prey in the same habitat.

After the fifth-graders finish their pinball games, they plan to make bar charts of the books the class has read this year, separating them by title, genre, length and popularity. Earlier this year, they did an immigration project using a database that included real manifests from ships that landed in Boston Harbor in 1840. Every team was given a family, and the goal was to set the family up in the New World with a balanced budget. This required using the database to find jobs, housing and even mates.

In all of the Edgewood School's software, there is very little pointing and clicking and no animated figures that haven't been created by the children themselves. Teachers shun drill software because they believe they can do a better job on basic skills themselves. "We know what we want to teach. The computer doesn't," explains fourth-grade teacher Barbara Black.

Mr. Crisci created most of the curriculum from scratch, using a language called MicroWorld's Logo from Logo Computer Systems Inc. and a software package called ClarisWorks from Apple Computer Inc.'s Claris subsidiary. There isn't much commercially available software that he considers truly educational.

Some industry executives say that is changing. As computers become more powerful and designers get more sophisticated, a new genre is emerging, they say. Multimedia programs that let children write and draw and create simulated villages, cities and their own characters are starting to appear.

Roger Schank, director of the Institute for the Learning Sciences at Northwestern University in Evanston, Ill., loathes the use of animated bears to teach children to read and laments the popularity of putting books on CD-ROM.

The software industry needs to invent a new way of learning, he maintains. He is working on "Broadcast News," a software program that lets kids make a TV news show, incorporating history, math and current events. "We are prepared to do better things," he says, if commercial companies will go along.

Jon Goldman, chief executive of ImaginEngine, a small software company in Mountain View, Calif., started out with a service that encourages children to write letters to characters by mailing back computer-generated responses that appear handwritten. Now he pursues software that will let children design their own computer characters and give them personalities.

"Just because we haven't reached the promised land of software excellence," he says, "doesn't mean that it's a mirage."

Choosing a Program

Some programs that educators recommend:

Primary Grades: My Own Stories, Storybook Weaver, both by MECC; Imagination Express, Edmark; Kid Pix, Broderbund. The Print Shop, Broderbund; Kid Works 2, Davidson.

Middle School: The Students Writing Center, Learning Co; SimTown, Maxis; HyperStudio, Roger Wagner Publishing; Amazing Animation, Claris; Fine Artist, Microsoft; Kid Cad, Davidson; Project Builder, MicroWorld.

High School: SimCity and SimCity 2000, Maxis; HyperCard, Apple; SuperCard, Allegiant.

Note: Most of these programs require adult support.

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